

CFTRI-MYSORE



13640

Organic reaction.

Tim

Organic Reactions

Organic Reactions

VOLUME X

EDITORIAL BOARD

ROGER ADAMS, *Editor-in-Chief*

A. H. BLATT

DAVID Y. CURTIN

VIRGIL BOEKELHEIDE

FRANK C. MCGREW

ARTHUR C. COPE

CARL NIEMANN

ADVISORY BOARD

LOUIS F. FIESER

JOHN R. JOHNSON

HAROLD R. SNYDER

ASSOCIATE EDITORS

ERNST D. BERGMANN

RAPHAEL PAPPO

DAVID GINSBURG

STANLEY M. PARMETER

ROBERT R. PHILLIPS

FORMER MEMBERS OF THE BOARD, NOW DECEASED

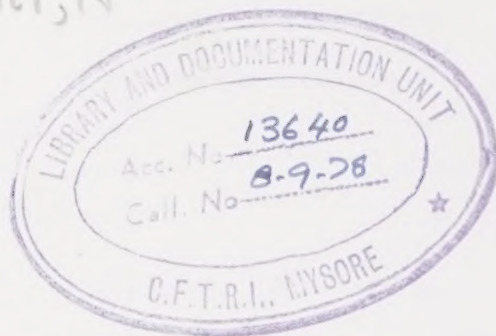
HOMER ADKINS

WERNER E. BACHMANN



ROBERT E. KRIEGER PUBLISHING COMPANY
HUNTINGTON, NEW YORK
1975

El, 5; 213th N
N42.10



Original Edition 1959
Reprinted 1975, with corrections

Printed and Published by
ROBERT E. KRIEGER PUBLISHING CO., INC.
645 NEW YORK AVENUE
HUNTINGTON, NEW YORK 11743

© Copyright by
ROGER ADAMS
Reprinted by Arrangement with
JOHN WILEY & SONS INC.

Library of Congress Catalog No. 42-20265

ISBN 0-88275-249-9

All rights reserved. No reproduction in any form of this book, in whole or in part (except for brief quotation in critical articles or reviews), may be made without written authorization from the publisher.

Printed in the United States of America

CFTRI-MYSORE



13640

Organic reaction.

PREFACE TO THE SERIES

In the course of nearly every program of research in organic chemistry the investigator finds it necessary to use several of the better-known synthetic reactions. To discover the optimum conditions for the application of even the most familiar one to a compound not previously subjected to the reaction often requires an extensive search of the literature; even then a series of experiments may be necessary. When the results of the investigation are published, the synthesis, which may have required months of work, is usually described without comment. The background of knowledge and experience gained in the literature search and experimentation is thus lost to those who subsequently have occasion to apply the general method. The student of preparative organic chemistry faces similar difficulties. The textbooks and laboratory manuals furnish numerous examples of the application of various syntheses, but only rarely do they convey an accurate conception of the scope and usefulness of the processes.

For many years American organic chemists have discussed these problems. The plan of compiling critical discussions of the more important reactions thus was evolved. The volumes of *Organic Reactions* are collections of chapters each devoted to a single reaction, or a definite phase of a reaction, of wide applicability. The authors have had experience with the processes surveyed. The subjects are presented from the preparative viewpoint, and particular attention is given to limitations, interfering influences, effects of structure, and the selection of experimental techniques. Each chapter includes several detailed procedures illustrating the significant modifications of the method. Most of these procedures have been found satisfactory by the author or one of the editors, but unlike those in *Organic Syntheses* they have not been subjected to careful testing in two or more laboratories. When all known examples of the reaction are not mentioned in the text, tables are given to list compounds which have been prepared by or subjected to the reaction. Every effort has been made to include in the tables all such compounds and references; however, because of the very nature of the reactions discussed and their frequent use as one of the several steps of syntheses in which not all of the intermediates have been isolated, some instances may well have been missed. Nevertheless, the investigator will be able

to use the tables and their accompanying bibliographies in place of most or all of the literature search so often required.

Because of the systematic arrangement of the material in the chapters and the entries in the tables, users of the books will be able to find information desired by reference to the table of contents of the appropriate chapter. In the interest of economy the entries in the indices have been kept to a minimum, and, in particular, the compounds listed in the tables are not repeated in the indices.

The success of this publication, which will appear periodically, depends upon the cooperation of organic chemists and their willingness to devote time and effort to the preparation of the chapters. They have manifested their interest already by the almost unanimous acceptance of invitations to contribute to the work. The editors will welcome their continued interest and their suggestions for improvements in *Organic Reactions*.

CONTENTS

CHAPTER	PAGE
1. THE COUPLING OF DIAZONIUM SALTS WITH ALIPHATIC CARBON ATOMS— <i>Stanley M. Parmerter</i>	1
2. THE JAPP-KLINGEMANN REACTION— <i>Robert R. Phillips</i>	143
3. THE MICHAEL REACTION— <i>Ernst D. Bergmann, David Ginsburg, and Raphael Pappo</i>	179
AUTHOR INDEX, VOLUMES 1-10	557
CHAPTER INDEX, VOLUMES 1-10	559
SUBJECT INDEX, VOLUME 10	561

CHAPTER 1

THE COUPLING OF DIAZONIUM SALTS WITH ALIPHATIC CARBON ATOMS

STANLEY M. PARMETER

Wheaton College

CONTENTS

	PAGE
INTRODUCTION	3
MECHANISMS OF THE REACTIONS	4
SCOPE AND LIMITATIONS	7
Ketones	7
β -Keto Acids, Esters, and Amides	10
Malonic Acids, Esters, and Amides	13
Arylacetic Acids and Esters	15
Nitriles	16
Sulfones	18
Nitro Compounds	19
Hydrocarbons	21
Hydrazones	24
Heterocyclic Compounds	26
SYNTHETIC APPLICATIONS	27
Cinnolines	27
Indazoles	29
Tetrazolium Salts	29
Thiocarbazones	29
Amidrazones	30
Amines	30
EXPERIMENTAL CONDITIONS	30
Diazonium Salts	30
Solvents	31
pH	31
Reactant Ratios	32
Time of the Reaction	32

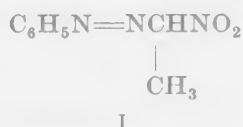
	PAGE
EXPERIMENTAL PROCEDURES	32
Ethyl α,β -Dioxobutyrate α -Phenylhydrazone	32
Ethyl Cyanoglyoxalate <i>m</i> -Chlorophenylhydrazone	33
1-Nitro-1- <i>p</i> -chlorophenylhydrazonoethane	33
1-(<i>p</i> -Nitrophenylazo)-2,3-dimethyl-1,3-butadiene	33
N,N'-Diphenyl-C-methylformazan	34
4-Hydroxy-3-methylcinnoline	34
TABULAR SURVEY	34
Table I. Coupling of Diazonium Salts with Ketones	35
A. Monoketones	35
B. β -Ketoaldehydes	39
C. β -Diketones	39
D. Cyclic β -Diketones	43
E. 4-Hydroxycinnolines from <i>o</i> -Aminoketones	46
Table II. Coupling of Diazonium Salts with β -Keto Acids, Esters, and Amides	49
A. β -Keto Acids	49
B. β -Keto Esters	51
C. β -Keto Amides	58
Table III. Coupling of Diazonium Salts with Malonic Acids, Esters, and Amides	64
A. Malonic Acids	64
B. Malonic Esters	65
C. Malonic Amides	67
Table IV. Coupling of Diazonium Salts with Arylacetic Acids and Esters	69
Table V. Coupling of Diazonium Salts with Nitriles	70
Table VI. Coupling of Diazonium Salts with Sulfones	80
Table VII. Coupling of Diazonium Salts with Nitro Compounds	83
Table VIII. Coupling of Diazonium Salts with Hydrocarbons	92
A. Unsaturated Hydrocarbons	92
B. Compounds Containing a Reactive Methyl Group	94
C. Cinnolines from <i>o</i> -Aminophenylethylenes	100
D. 4-Hydroxycinnolines from <i>o</i> -Aminophenylacetylenes	102
E. Indazoles from <i>o</i> -Toluidines	103
Table IX. Coupling of Diazonium Salts with Hydrazones	106
A. Simple Hydrazones	106
B. Hydrazones of Sugars	115
C. Diformazans from Hydrazones and Diamines	116
D. Diformazans from Dihydrazones	117
E. Diformazans from Diketalsulfonylguanidines	118
F. Hydroximes Which Couple with Elimination of a Substituent	118

	PAGE
Table X. Coupling of Diazonium Salts with Heterocyclic Compounds	121
A. 5 Pyrazolones	121
B. Miscellaneous Heterocyclic Compounds	129
Table XI. Coupling of Diazonium Salts with Miscellaneous Compounds	135

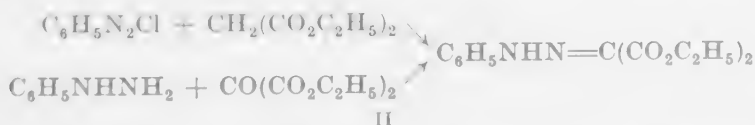
INTRODUCTION

A diazonium salt will couple with an aliphatic compound containing an activated carbon-hydrogen bond. This discussion is limited to those reactions in which both nitrogen atoms of the diazonium salt are retained in the resulting molecule. The discussion is further limited by the exclusion of coupling reactions which occur with the elimination of a group from an activated methinyl compound, the Japp-Klingemann reaction, as these reactions are discussed in Chapter 2.

Victor Meyer was the first to report the coupling of a diazonium salt with an activated aliphatic carbon atom.¹ He found that benzenediazonium sulfate reacts with the sodium salt of nitroethane to give a colored product which was assigned the azo structure I.



Coupling with other nitroparaffins²⁻⁵ as well as with ethyl acetoacetate^{6,7} was soon reported. A question regarding the structure of the reaction products arose when it was discovered that benzenediazonium chloride coupled with diethyl malonate to give a product identical with the phenylhydrazone of diethyl mesoxalate (II).^{8a}



Much of the early work with the coupling reaction was prompted by the desire to determine whether the products were of the azo or hydrazone

¹ Meyer and Ambühl, *Ber.*, **8**, 751 (1875).

² Meyer and Ambühl, *Ber.*, **8**, 1073 (1875).

³ Fries, *Ber.*, **8**, 1078 (1875).

⁴ Meyer, *Ber.*, **9**, 384 (1876).

⁵ Zublin, *Ber.*, **10**, 2087 (1877).

⁶ Meyer, *Ber.*, **10**, 2075 (1877).

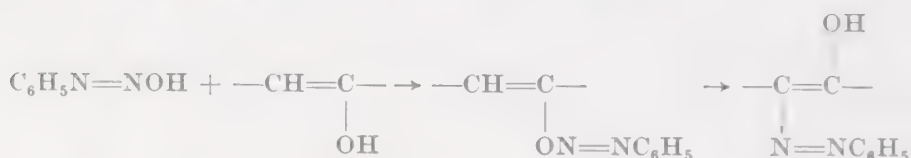
⁷ Zublin, *Ber.*, **11**, 1417 (1878).

^{8a} Meyer, *Ber.*, **21**, 118 (1888).

structure. It is difficult to establish with certainty the structures in such cases where two tautomeric forms are possible. However, it is generally assumed that the hydrazone is the stable form whenever coupling occurs at a methyl or methylene carbon. Recently, Wiley and Jarboe have presented ultraviolet and infrared absorption data which corroborate this view.^{8b} In the limited number of compounds where coupling occurs on a methinyl carbon without the elimination of a group only the azo structure is possible.

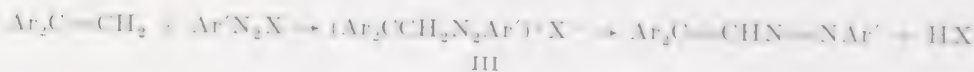
MECHANISMS OF THE REACTIONS

Various mechanisms for the coupling reaction have been proposed. Dimroth observed that reaction occurred only with the enol forms of various ketones.⁹ He proposed that the first product was an enol ether which rearranged to give the final product. The isolation of intermediate



O-azo compounds in certain instances gave further support to his proposal.¹⁰⁻¹² However, these intermediates were isolated only from highly substituted aliphatic reactants such as tribenzoylmethane. It is probable that this mechanism is applicable in special cases.

When certain *z,z*-diarylethylenes react with diazonium salts, a crystalline intermediate can be isolated.^{13,14} This is considered to be the carbonium salt III. The salt readily loses hydrogen halide to give an



azo compound. Since these intermediates have been isolated only with rather complex molecules, it may be unwise to propose their formation as part of a general mechanism for coupling with all unsaturated hydrocarbons and enols.

Busch has studied the mechanism of the reaction of diazonium salts

^{8b} Wiley and Jarboe, *J. Am. Chem. Soc.*, **77**, 403 (1955).

⁹ Dimroth, *Ber.*, **40**, 2404 (1907).

¹⁰ Dimroth and Hartmann, *Ber.*, **41**, 4012 (1908).

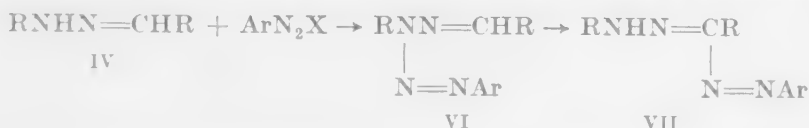
¹¹ Dimroth, Leichtlin, and Friedemann, *Ber.*, **50**, 1534 (1917).

¹² Auwers, *Ann.*, **378**, 243 (1910).

¹³ Dilthey and Blankenburg, *J. prakt. Chem.*, [2], **142**, 177 (1935).

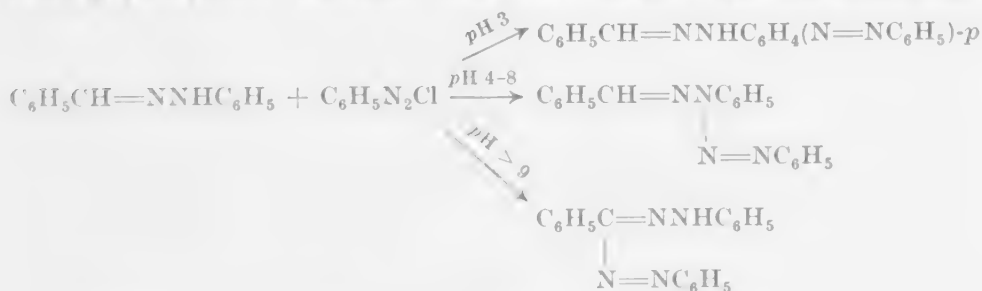
¹⁴ Wizinger and Cyriax, *Helv. Chim. Acta*, **28**, 1018 (1945).

with hydrazones.¹⁵⁻¹⁸ From the observation that primary hydrazones (IV) couple readily with diazonium salts, whereas secondary hydrazones (V) do not react,¹⁹ he proposed that the first product was an N-azo compound (VI) which rearranged to give the formazan derivative VII.* A crystalline intermediate, assumed to be the N-azo compound, was isolated from the reaction of benzenediazonium chloride with benzaldehyde



phenylhydrazone in alcoholic sodium acetate.¹⁸ Evaporation of an ether solution of this compound produced a formazan.

More recent study of the reaction between benzaldehyde phenylhydrazone and benzenediazonium chloride has shown that the product was dependent on the pH of the reaction medium.^{19a,19b} In a solution of pH 3, benzaldehyde *p*-phenylazophenylhydrazone was isolated. Reaction at pH values of 4 to 8 produced up to 66% yields of 4-benzylidene-1,3-diphenyl-1-tetrazene, whereas at a pH greater than 9 the product was N,N',C-triphenylformazan. The tetrazene changed to the formazan within a few hours at room temperature or rapidly when heated to 90°. Rearrangement also occurred in pyridine or ethanolic potassium hydroxide. The fact that no 1-phenylazo-2-naphthol was formed when the rearrangement was carried out in ethanolic potassium hydroxide containing β -naphthol indicated that the reaction was intramolecular.



¹⁸ Busch and Pfeiffer, *Ber.*, **59**, 1162 (1926).

¹⁰ Busch and Schmidt, *Ber.*, **63**, 1950 (1930).

¹⁷ Busch and Schmidt, *J. prakt. Chem.*, [2], **129**, 151 (1931).

¹⁹ Busch and Schmidt, *J. prakt. Chem.*, [2], **131**, 182 (1931).

¹⁹ von Pechmann, *Ber.*, **27**, 1679 (1894).

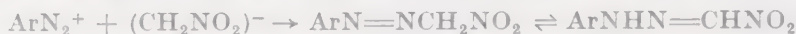
* These compounds are named as derivatives of the hypothetical formazan, $H_2NN=CHN-NH$.

¹⁰⁰ Hauptmann and Périisse, *Experientia*, **10**, 60 (1954) [*C. A.* **49**, 4554 (1955)].

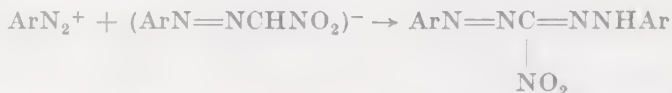
¹⁰⁶ Hauptmann and Périssac, *Chem. Ber.*, **89**, 1081 (1956).

However, when the tetrazene was dissolved in a cold solution of hydrogen chloride in ethanol, benzaldehyde phenylhydrazone and benzenediazonium chloride were regenerated.

Most of the current theories formulate the reaction as the direct attack of the diazonium cation on a carbanion or a carbon atom with high electron density.^{19c,19d} Tarbell has proposed such a mechanism for the reaction of a diazonium salt with nitromethane.²⁰ The reaction of the



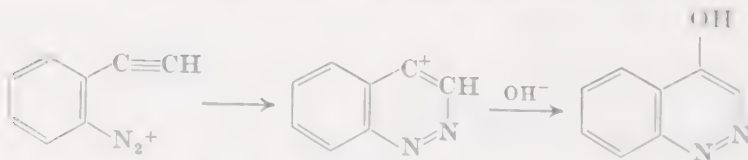
product with a second molecule of diazonium salt also was postulated as being ionic in nature.



Although the second reaction seems to be at variance with the experiments of Busch mentioned above, it should be noted that the facts given by Busch do not exclude the possibility of an ionic mechanism for the reaction. Since the reactions in the system appear to be reversible, the isolation of N-azo compounds and the fact that they can generate the final product do not prove that they are intermediates. An alternative explanation for the observation that secondary hydrazones, such as V above, do not react may be that the coupling reaction requires the resonance-stabilized carbanion $\text{VIIIa} \leftrightarrow \text{VIIIb}$.²¹



The diazonium salts prepared from *o*-aminophenylacetylenes undergo intramolecular coupling to yield 4-hydroxycinnolines. Schofield and his co-workers believe that the first step in this reaction is the coordination of the diazonium cation with one carbon atom of the acetylene, followed by the addition of hydroxyl ion to the other carbon atom.^{22,23}



^{19c} Hünig and Boes, *Ann.*, **579**, 28 (1953).

^{19d} Scott, O'Sullivan, and Reilly, *J. Am. Chem. Soc.*, **75**, 5309 (1953).

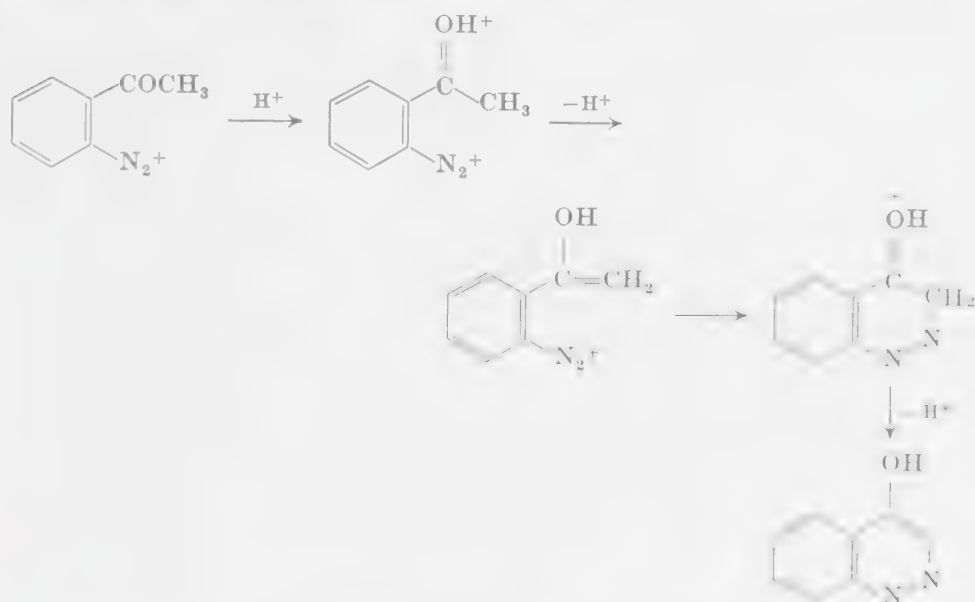
²⁰ Tarbell, Todd, Paulson, Liniccum, and Wyszath, *J. Am. Chem. Soc.*, **70**, 1551 (1948).

²¹ D. S. Tarbell, private communication.

²² Schofield and Simpson, *J. Chem. Soc.*, **1945**, 520.

²³ Schofield and Swain, *J. Chem. Soc.*, **1949**, 2393.

Diazotized *o*-aminoacetophenones also couple intramolecularly with the formation of 4-hydroxycinnolines. This reaction, which is favored by a strongly acidic reaction medium, is believed to proceed through an acid-catalyzed enolization of the carbonyl group.²⁴

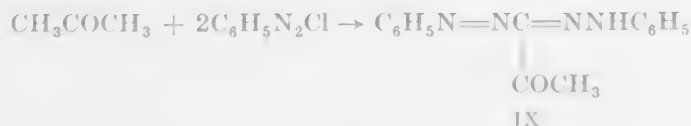


SCOPE AND LIMITATIONS

Since the principal factor that influences this reaction is the nature of the aliphatic reactant rather than that of the diazonium salt, the following discussion is based upon the types of compounds that undergo coupling.

Ketones

Few examples of the reaction of a simple ketone with a diazonium salt have been reported. Acetone reacts with benzenediazonium chloride in alkaline solution to give a product²⁵ that was later identified as methyl formazyl ketone (IX).²⁶ The methyl group in pyruvic acid likewise reacts with two molecules of diazonium salt.²⁷ When one of the hydrogen atoms of acetone is replaced by an activating group, the



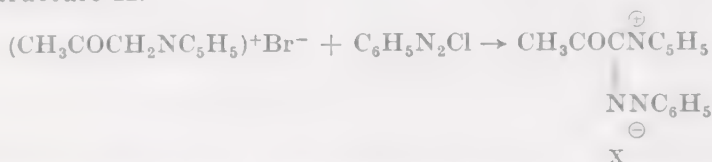
²⁴ Schofield and Simpson, *J. Chem. Soc.*, **1948**, 1170.

²⁵ Bamberger and Wulz, *Ber.*, **24**, 2793 (1891).

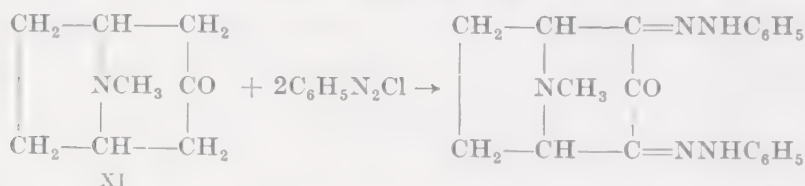
²⁶ von Pechmann, *Ber.*, **25**, 3190 (1892).

²⁷ Bamberger and Müller, *Ber.*, **27**, 147 (1894).

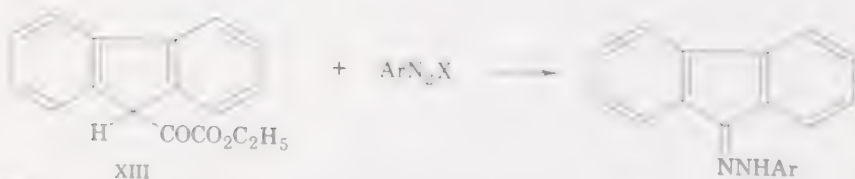
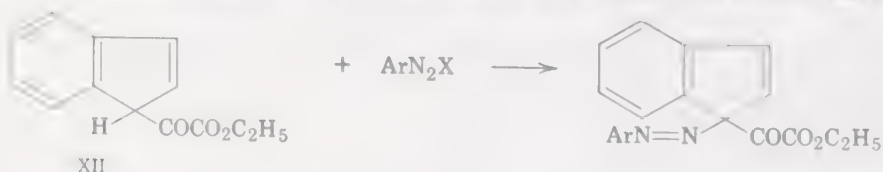
methylene carbon is the one attacked. Compounds of this type that have been investigated include chloroacetone,²⁸ 2,4-dinitrophenylacetone,²⁹ acetylpyridinium bromide,³⁰ and a variety of 3-acetyl-1,2,4-oxadiazoles.^{31,32} The product from acetylpyridinium bromide had the betaine structure X.



Dieckmann reported that cyclopentane-1,2-dione reacts with benzene-diazonium chloride to give the 1-phenylhydrazone of cyclopentane-1,2,3-trione.³³ The only instance of the coupling of 2 moles of a diazonium salt with a cyclic ketone was the reaction used by Willstätter to show the presence of two active methylene groups in tropinone (XI).³⁴



The reaction of a diazonium salt with 1-ethoxalylindene (XII) produces the 1-arylazocompound.³⁵ This contrasts with the observation that the



²⁸ Favrel, *Bull. soc. chim. France*, [4], **41**, 1494 (1927).

²⁹ Borsche, *Ber.*, **42**, 601 (1909).

³⁰ Krollpfeiffer and Braun, *Ber.*, **70**, 89 (1937).

³¹ Merckx, *Chimie & industrie*, **63**, No. 3 bis, 453 (1950).

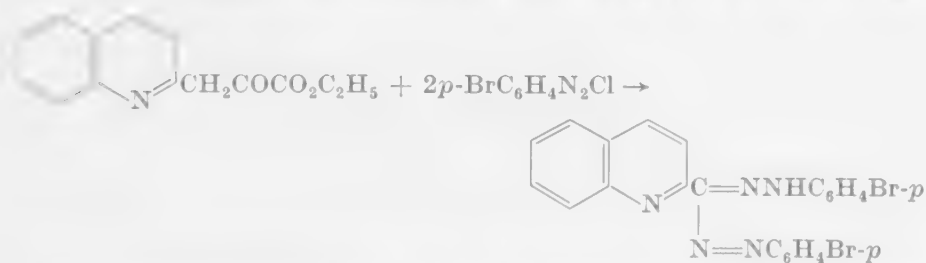
³² Merckx, *Bull. soc. chim. belges*, **58**, 183 (1949).

³³ Dieckmann, *Ber.*, **35**, 3201 (1902).

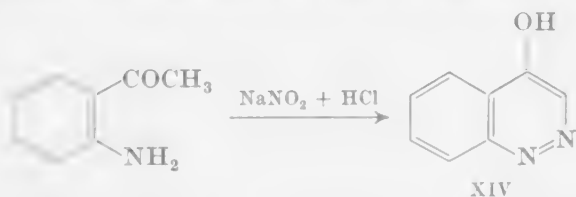
³⁴ Willstätter, *Ber.*, **30**, 2679 (1897).

³⁵ Wislicenus and Hentrich, *Ann.*, **436**, 9 (1924).

ethoxalyl group was eliminated when 9-ethoxalylfluorene (XIII) was treated with a diazonium salt.³⁶ The reaction of heterocyclic esters with 2 moles of a diazonium salt is a convenient preparation of C-heterocyclic formazans.^{36a} Ethyl 2-quinolylpyruvate, for example, reacts with *p*-bromobenzenediazonium chloride to give a 79% yield of the formazan.



The only acetophenones that have been shown to undergo coupling are the *o*-aminoacetophenones. When these amines are diazotized, reaction occurs intramolecularly to give 4-hydroxycinnolines. Although this reaction is favored by the presence of electronegative groups ortho or para to the amino group, a 70-75% yield of 4-hydroxycinnoline (XIV)



could be obtained by warming a solution of diazotized *o*-aminoacetophenone in hydrochloric acid.³⁷ This transformation proceeds smoothly with a variety of substituted *o*-aminoacetophenones. It has been extended to include *o*-aminophenacyl halides which give 3-halogenated 4-hydroxycinnolines.^{34,38} Higher homologs of *o*-aminoacetophenone produce the corresponding 3-alkyl-4-hydroxycinnolines.³⁹⁻⁴¹

The methylene group in β -diketones reacts readily with diazonium salts. The product may be formulated as the monohydrazone of a triketone. Benzoylacetone, for example, has been converted into the monophenylhydrazone XV in 90% yield.⁴² A variety of β -diketones has been employed in the same general reaction. Cyclic β -diketones, such as

³⁶ Kuhn and Levy, *Ber.*, **61**, 2240 (1928).

^{36a} Ried and Hoffschmidt, *Ann.*, **581**, 23 (1953).

³⁷ Keneford and Simpson, *J. Chem. Soc.*, **1947**, 917.

³⁸ Schofield, Swain, and Theobald, *J. Chem. Soc.*, **1949**, 2399.

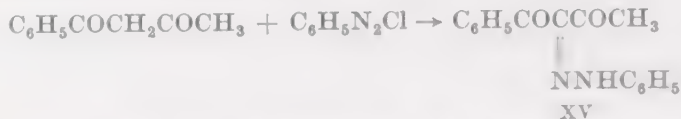
³⁹ Leonard and Boyd, *J. Org. Chem.*, **11**, 419 (1946).

⁴⁰ Keneford and Simpson, *J. Chem. Soc.*, **1948**, 354.

⁴¹ Keneford and Simpson, *J. Chem. Soc.*, **1948**, 2318.

⁴² Chattaway and Lye, *J. Chem. Soc.*, **1933**, 480.

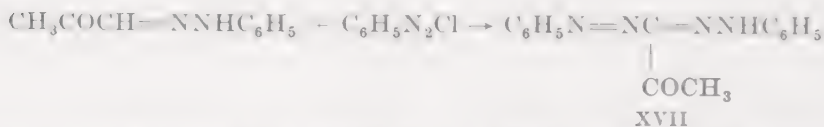
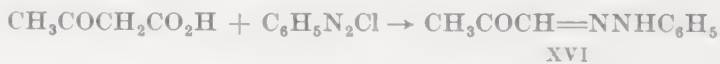
cyclohexane-1,3-dione,⁴³ methone,⁴⁴⁻⁴⁶ and indan-1,3-dione^{47,48} react as readily as the acyclic analogs.



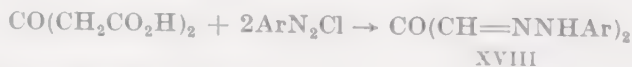
A limited number of β -keto aldehydes has been investigated.⁴⁹⁻⁵¹ In these compounds, the methylene group reacts in the same manner as in β -diketones.

β -Keto Acids, Esters, and Amides

When a β -keto carboxylic acid is treated with a diazonium salt, carbon dioxide is eliminated. The product from the reaction of benzenediazonium chloride with acetoacetic acid is the 1-phenylhydrazone of pyruvaldehyde (XVI). If 2 moles of diazonium salt are employed, methyl formazyl ketone (XVII) is the product.⁵² In carrying out this reaction, the general practice is to saponify a β -keto ester and then to add the diazonium salt solution directly to the hydrolysis mixture without isolation of the unstable β -keto acid.⁵³⁻⁵⁵



Acetonedicarboxylic acid reacts with 2 moles of diazonium salt with the elimination of both carboxyl groups.^{56,57} The resulting product is a mesoxaldehyde diarylhydrazone (XVIII).



⁴³ Vorländer, *Ann.*, **294**, 253 (1897).

⁴⁴ Lifschitz, *Ber.*, **47**, 1401 (1914).

⁴⁵ Iyer and Chakravarti, *J. Indian Inst. Sci.*, **17A**, 41 (1934) [*C. A.*, **28**, 4399 (1934)].

⁴⁶ Iyer, *J. Indian Inst. Sci.*, **21A**, Pt. 6, 65 (1938) [*C. A.*, **33**, 148 (1939)].

⁴⁷ Wislicenus and Reitzenstein, *Ann.*, **277**, 362 (1893).

⁴⁸ Das and Ghosh, *J. Am. Chem. Soc.*, **43**, 1739 (1921).

⁴⁹ Beyer and Claisen, *Ber.*, **21**, 1697 (1888).

⁵⁰ Benary, Meyer, and Charisius, *Ber.*, **59**, 108 (1926).

⁵¹ Benary, *Ber.*, **60**, 914 (1927).

⁵² Bamberger and Lorenzen, *Ber.*, **25**, 3539 (1892).

⁵³ Japp and Klingemann, *J. Chem. Soc.*, **53**, 519 (1888).

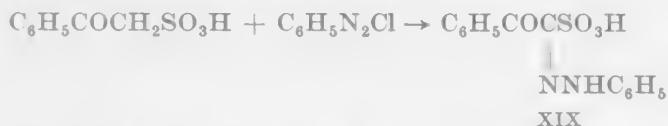
⁵⁴ Japp and Klingemann, *Ann.*, **247**, 190 (1888).

⁵⁵ Reynolds and Van Allan, *Org. Syntheses*, **32**, 84 (1952).

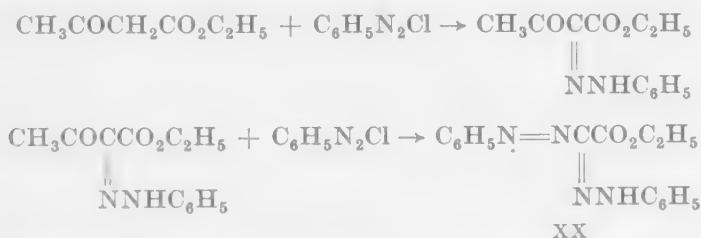
⁵⁶ von Pechmann and Jenisch, *Ber.*, **24**, 3255 (1891).

⁵⁷ von Pechmann and Vanino, *Ber.*, **27**, 219 (1894).

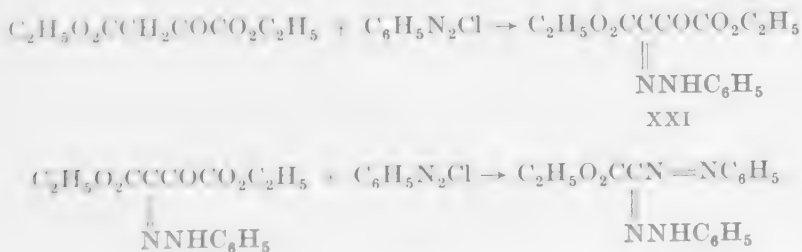
A β -keto sulfonic acid retains the acid group when it couples with a diazonium salt.^{58,59} For example, the phenylhydrazone XIX has been prepared in 60% yield from 2-oxo-2-phenylethane-1-sulfonic acid.



The reactions of β -keto esters with diazonium salts have been studied extensively. Products from ethyl acetoacetate and over fifty different diazonium salts have been reported. Good yields of the α -hydrazones of α,β -diketo esters are obtained if 1 mole of the diazonium salt is employed. However, the use of 2 moles of benzenediazonium chloride causes the elimination of the acetyl group to give an 80% yield of C-carbethoxy-N,N'-diphenylformazan (XX).⁶⁰



Diethyl oxaloacetate likewise can react with 1 or 2 moles of benzenediazonium chloride.⁶¹⁻⁶³ If 1 mole of the salt is used, the product is diethyl dioxosuccinate phenylhydrazone (XXI). The addition of 2 moles of diazonium salt in strongly alkaline solution causes the replacement of the ethoxalyl group.



There are no reports of the elimination of groups other than acetyl and ethoxalyl when 2 moles of a diazonium salt react with a β -keto ester

⁵⁸ Parkes and Fisher, *J. Chem. Soc.*, **1936**, 83.

⁵⁹ Parkes and Tinsley, *J. Chem. Soc.*, **1934**, 1861.

⁶⁰ Bamberger and Wheelwright, *J. prakt. Chem.*, [2], **65**, 125 (1902).

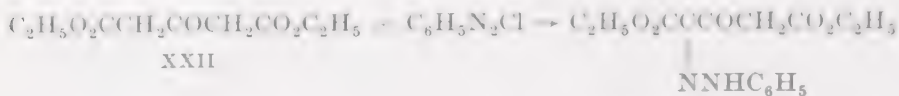
⁶¹ Wislicenus and Jensen, *Ber.*, **25**, 3448 (1892).

⁶² Rabiachong, *Bull. soc. chim. France*, [3], **31**, 76 (1904).

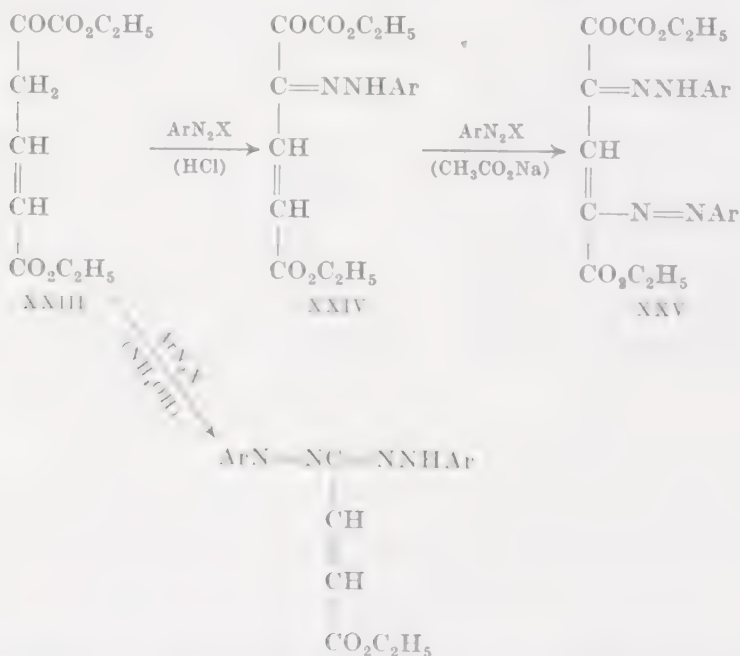
⁶³ Rabiachong, *Bull. soc. chim. France*, [3], **31**, 83 (1904).

containing a methylene group. However, by analogy with the Japp-Klingemann reaction (p. 143), it would be expected that other acyl groups could be eliminated as well.

Diethyl acetonedicarboxylate (XXII) reacts smoothly with 1 mole of diazonium salt.^{64,65} There have been no reports of further reaction with the second methylene group present in the molecule.



Diethyl oxalocrotonate (XXIII) may be regarded as a vinylog of diethyl oxaloacetate. Its behavior with diazonium salts depends upon the *pH* of the reaction mixture.⁶⁶ When the ester is treated with excess *p*-bromobenzenediazonium chloride in ethanolic hydrochloric acid, the only product is the monophenylhydrazone XXIV. This product is converted into the azo derivative XXV if sodium acetate is added. The original ester reacts with 2 moles of diazonium salt in dilute ammonia with the loss of the ethoxalyl group.



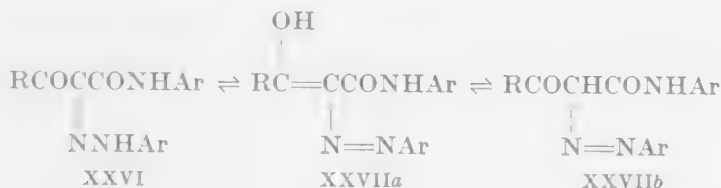
The coupling of diazonium salts with β -keto amides has been studied extensively, because the products have found use as yellow dyes and

⁶⁴ Bülow and Höpfner, *Ber.*, **34**, 71 (1901).

⁶⁵ Bülow and Göller, *Ber.*, **44**, 2835 (1911).

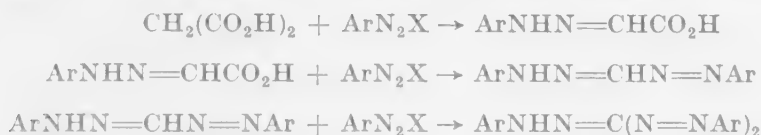
⁶⁶ Prager, *Ann.*, **338**, 360 (1905).

pigments. The Hansa Yellows are obtained from the reactions of acetacetanilides with various diazonium salts.⁶⁷⁻⁶⁹ Many variations in the anilide as well as in the diazonium salt have been studied in attempts to improve the color, stability, and solubility of the resulting dyes. Limitations of space preclude a survey of the extensive patent literature on this subject. However, those β -keto amides whose coupling has been reported in the general literature are included in Table II c . The dyes may be formulated as existing in both hydrazone (XXVI) and azo (XXVIIa and b) tautomeric forms.

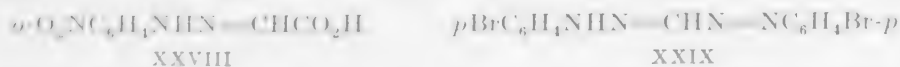


Malonic Acids, Esters, and Amides

Malonic acid can react with 1, 2, or 3 moles of a diazonium salt. It appears that the reaction proceeds through the following steps, with decarboxylation occurring in the first and second stages.⁷⁰ Even when



equimolecular amounts of acid and salt are used, the reaction usually gives a mixture of the first two products. The relative amounts of these substances formed depend upon the nature of the diazonium salt employed. Busch and Wolbring were able to isolate the phenylhydrazone XXVIII in 50% yield from the reaction of malonic acid with *o*-nitrobenzenediazonium chloride, but under similar conditions *p*-bromobenzenediazonium chloride gave mainly *N,N'*-di-(*p*-bromophenyl)formazan



(XXIX).⁷¹ A formazan derivative is the main product with either 1 or 2 moles of most diazonium salts.

⁶⁷ Fierz-David and Ziegler, *Helv. Chim. Acta*, **11**, 776 (1928).

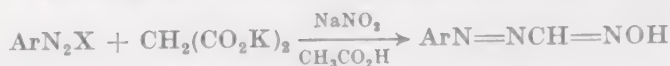
⁶⁸ Burr and Rowe, *J. Soc. Dyers Colourists*, **44**, 205 (1928) [*C. A.*, **22**, 3400 (1928)].

⁶⁹ Rowe, Burr, and Corbishley, *J. Soc. Dyers Colourists*, **42**, 80 (1926) [*C. A.*, **20**, 1718 (1926)].

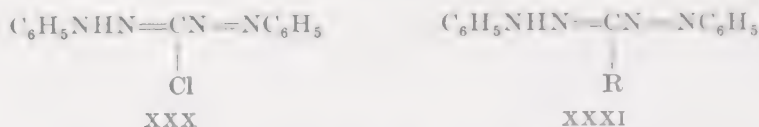
⁷⁰ von Pechmann, *Ber.*, **25**, 3175 (1892).

⁷¹ Busch and Wolbring, *J. prakt. Chem.*, [2], **71**, 366 (1905).

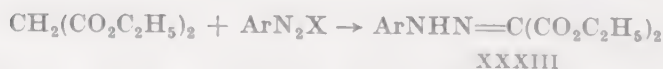
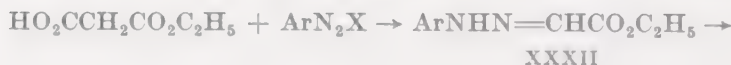
If an acidic solution of a diazonium salt is added to a solution of potassium malonate and sodium nitrite, both nitrosation and coupling take place to yield the azo derivative of formaldoxime.⁷¹



Formazyl chloride (XXX) is obtained from the reaction of 2 moles of benzenediazonium chloride with chloromalonic acid.⁷² Alkylmalonic acids are converted into formazyl alkanes (XXXI) in a similar reaction.⁷³



When malonic acid monoethyl ester reacts with a diazonium salt, carbon dioxide is eliminated with the formation of an arylhydrazone of ethyl glyoxalate (XXXII).^{74a} This hydrazone can react with a second mole of diazonium salt to give the formazan XXXIIa. It appears that the formazan is the only product isolated unless there is an *o*-substituent in the diazonium salt.^{19c, 74b} Diethyl malonate, on the other hand, gives the arylhydrazone of diethyl mesoxalate (XXXIII).^{74c} Similarly,



malonamide and its N-substituted derivatives are converted into the hydrazones of the corresponding mesoxalamides.⁷⁵

Diethyl glutaconate (XXXIV) may be regarded as a vinyllog of diethyl malonate. Henrich has studied its reactions with both 1 and 2 equivalents of diazonium salt.⁷⁶ The use of 1 equivalent of salt gives diethyl oxoglutaconate phenylhydrazone (XXXV). A second equivalent couples at the other α -carbon atom.

⁷¹ Fusco and Romani, *Gazz. chim. ital.*, **76**, 419 (1946).

⁷² Walker, *J. Chem. Soc.*, **123**, 2775 (1923).

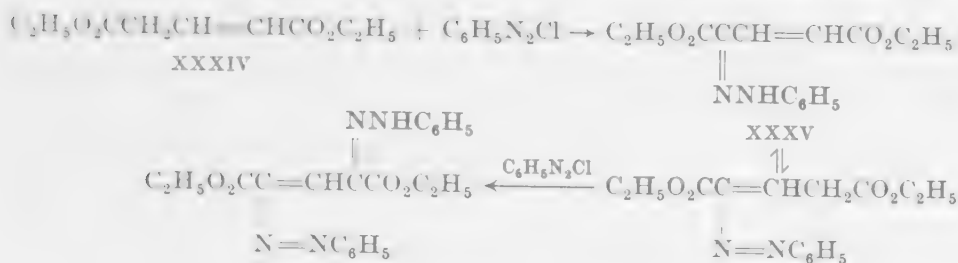
^{74a} Leonard, Boyd, and Herbrandson, *J. Org. Chem.*, **12**, 47 (1947).

^{74b} S. Parmeter and E. J. Hodges, unpublished observations.

^{74c} Hantzsch and Thompson, *Ber.*, **38**, 2266 (1905).

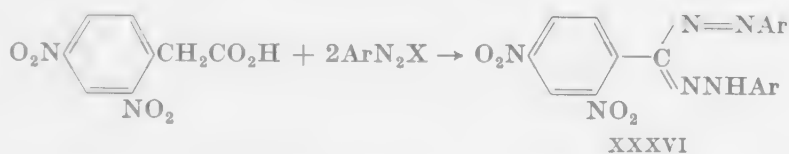
⁷⁵ Whiteley and Yapp, *J. Chem. Soc.*, **1927**, 521.

⁷⁶ Henrich et al., *Ann.*, **376**, 121 (1910).

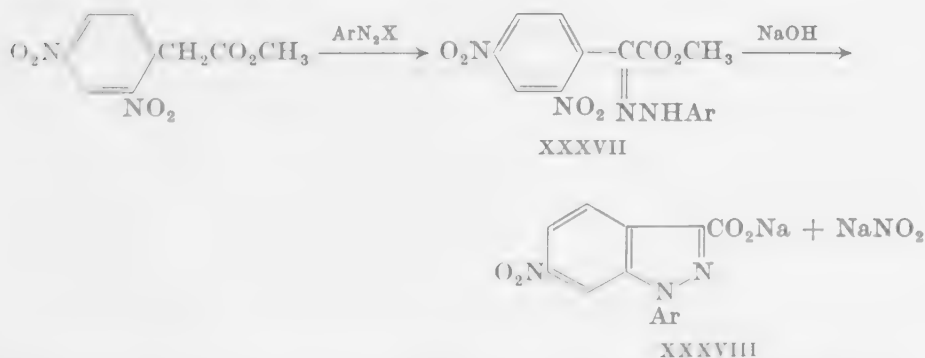


Arylacetic Acids and Esters

The only arylacetic acid that has been observed to couple with diazonium salts is 2,4-dinitrophenylacetic acid.⁷⁷ Decarboxylation occurs as two molecules of the salt attack the α -carbon atom to yield the formazan derivative XXXVI.



Reactions of a variety of diazonium salts with methyl 2,4-dinitrophenylacetate have given good yields of the hydrazones of methyl 2,4-dinitrophenylglyoxalate (XXXVII).^{78,79} These hydrazones undergo ring closure in the presence of alkali with the formation of 1-aryllindazoles (XXXVIII).⁷⁸⁻⁸⁰



Although diethyl homophthalate does not react with benzenediazonium chloride, homophthalic anhydride in ethanol-chloroform solution is

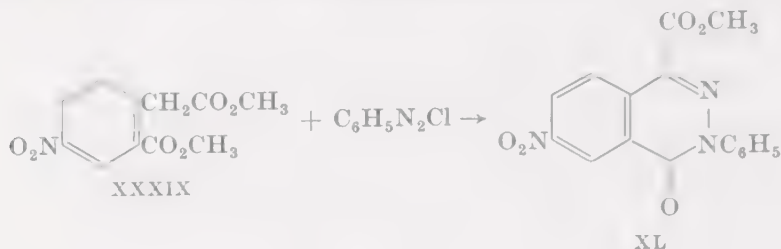
⁷⁷ Parkes and Aldis, *J. Chem. Soc.*, **1938**, 1841.

⁷⁸ Borsche and Bütchli, *Ann.*, **522**, 285 (1936).

⁷⁹ Borsche and Diacont, *Ann.*, **510**, 287 (1934).

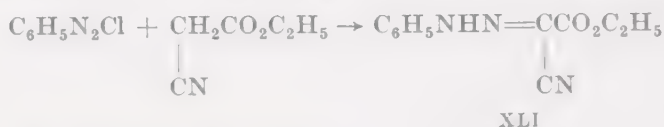
⁸⁰ Meyer, *Ber.*, **22**, 319 (1889).

converted into the α -phenylhydrazono compound.⁸¹ Dimethyl 5-nitrohomophthalate (XXXIX) also couples, and a simultaneous ring closure produces the substituted dihydropthalazone XL.⁷⁹



Nitriles

A nearly quantitative yield of ethyl cyanoglyoxalate phenylhydrazone (XLI) is obtained from ethyl cyanoacetate and benzenediazonium



chloride in the presence of sodium acetate or sodium carbonate.⁸² A variety of diazonium salts has been used in similar reactions with esters of cyanoacetic acid. Other nitriles that undergo the same type of coupling contain a methylene group between the cyano group and some other activating group. Examples are malononitrile,^{83,84} cyanoacetaldehyde,^{85,86} cyanoacetanilide,^{74a} ethyl cyanopyruvate,^{86,87} nitroacetonitrile,^{88,89} β -iminonitriles,^{90,91} and β -sulfonitriles.^{92,93} The coupling products from β -ketonitriles form chromium complexes that are dyes.⁹⁴ Cyanoacetic acid combines with 2 equivalents of benzenediazonium chloride to produce formazyl cyanide.^{95a}

⁸¹ Dieckmann and Meiser, *Ber.*, **41**, 3253 (1908).

⁸² Krückeberg, *J. prakt. Chem.*, [2], **49**, 321 (1894).

⁸³ Schmidtman, *Ber.*, **29**, 1168 (1896).

⁸⁴ Lythgoe, Todd, and Topham, *J. Chem. Soc.*, **1944**, 315.

⁸⁵ Claisen, *Ber.*, **36**, 3664 (1903).

⁸⁶ Borsche and Manteuffel, *Ann.*, **512**, 97 (1934).

⁸⁷ Fleischhauer, *J. prakt. Chem.*, [2], **47**, 375 (1893).

⁸⁸ Steinkopf and Bohrmann, *Ber.*, **41**, 1044 (1908).

⁸⁹ Steinkopf, *J. prakt. Chem.*, [2], **81**, 193 (1910).

⁹⁰ von Meyer, *J. prakt. Chem.*, [2], **52**, 81 (1895).

⁹¹ von Meyer, *J. prakt. Chem.*, [2], **78**, 497 (1908).

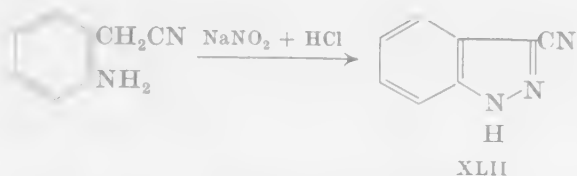
⁹² Tröger and Berndt, *J. prakt. Chem.*, [2], **102**, 1 (1921).

⁹³ Tröger and Wunderlich, *J. prakt. Chem.*, [2], **101**, 157 (1921).

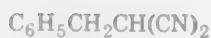
⁹⁴ Long, *J. Am. Chem. Soc.*, **69**, 990 (1947).

^{95a} Wedekind, *Ber.*, **30**, 2993 (1897).

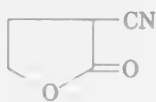
Ring closure to give a 71% yield of 3-cyanoindazole (XLII) takes place when *o*-aminophenylacetonitrile is diazotized.^{95b} It appears that this cyclization has not been investigated with nuclear-substituted *o*-aminophenylacetonitriles.



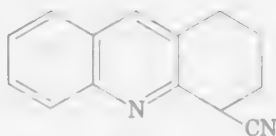
Nitriles in which the cyano group is adjacent to a methinyl carbon vary in their reactions with diazonium salts. Benzylmalononitrile (XLIII),⁹⁶ α -cyano- γ -hydroxybutyric acid lactone (XLIV),⁹⁷ 1,2,3,4-



XLIII



XLIV

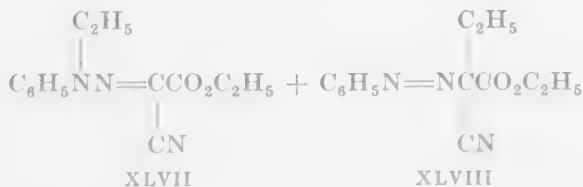


XLV



XLVI

tetrahydroacridine-4-carbonitrile (XLV),⁹⁸ and α -arylsulfonylpropionitriles (XLVI)⁹³ form the azo compounds. Ethyl α -cyanobutyrate is reported to undergo two different reactions. With this ester Favrel isolated the hydrazone XLVII formed by migration of the ethyl group,



^{95b} Pachorr and Hoppe, *Ber.*, **43**, 2543 (1910).

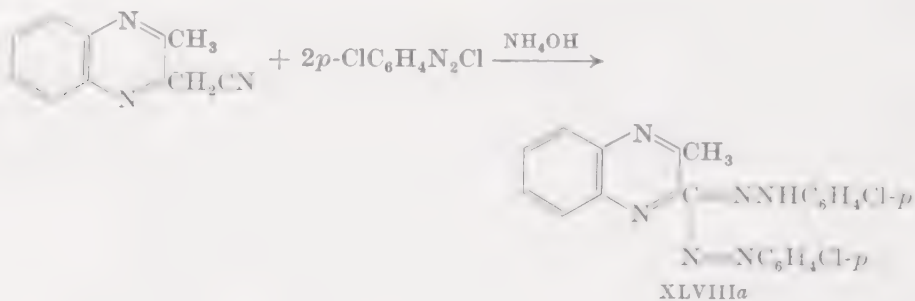
⁹⁶ Curtin and Russell, *J. Am. Chem. Soc.*, **73**, 4975 (1951).

⁹⁷ Feofilaktov and Onishchenko, *J. Gen. Chem. U.S.S.R.*, **9**, 325 (1939) [*C. A.*, **34**, 379 (1940)].

⁹⁸ Borache and Mantouff, *Ann.*, **534**, 56 (1938).

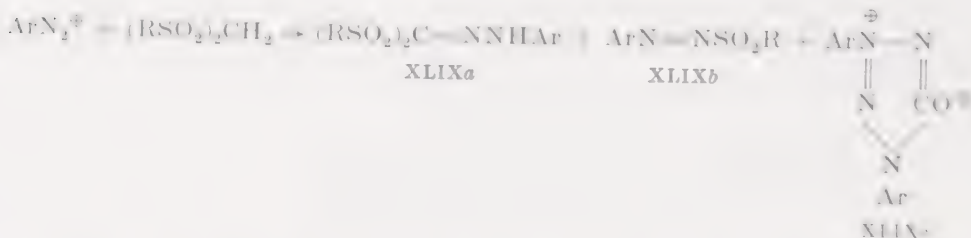
as well as the expected azo compound XLVIII.⁹⁹ When an acetyl group is attached at the methinyl carbon, as in ethyl α -cyanoacetoacetate, the Japp-Klingemann reaction occurs with loss of the acetyl group.¹⁰⁰

One example of the loss of the cyano group during a coupling reaction has been reported.^{36a} The products isolated from the reaction of 3-methylquinoxaline-2-acetonitrile and *p*-chlorobenzenediazonium chloride in dilute ammonium hydroxide were the formazan (XLVIIIa) and urea.



Sulfones

A methylene group adjacent to two sulfonyl groups is attacked by a diazonium salt. The normal product is the monophenylhydrazone XLIXa even when an excess of the salt is used.¹⁰¹ However, in the reaction of *p*-nitrobenzenediazonium fluoroborate with various sulfones two other products, the arylazosulfone XLIXb and the tetrazolium betaine XLIXc, were isolated also.^{19c}



Other sulfones that couple with diazonium salts have a methylene group between a sulfonyl and some other activating group such as nitro,^{100, 102} cyano,^{19c, 92, 93} carboxyl,^{19c, 92} carbethoxy,^{19c, 92} or carboxamide.^{19c, 92} Glass prepared a series of dyes from the cyclic amide of

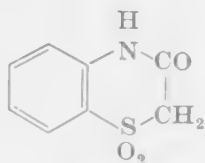
⁹⁹ Favrel, *Bull. soc. chim. France*, [4], **47**, 1290 (1930).

¹⁰⁰ Favrel, *Bull. soc. chim. France*, [3], **27**, 200 (1902).

¹⁰¹ Backer, *Rec. trav. chim.*, **70**, 733 (1951).

¹⁰² Tröger and Nolte, *J. prakt. chem.*, [2], **101**, 136 (1921).

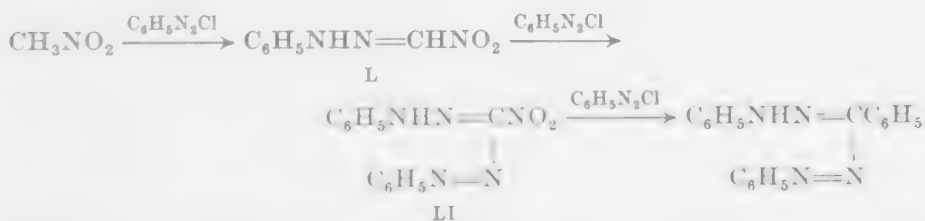
o-aminophenylsulfonylacetic acid (sulfazone) (XLIXd) and various diazonium salts.¹⁰³



XLIXd

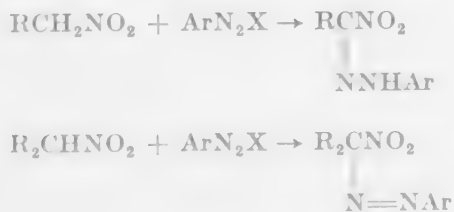
Nitro Compounds

A nitroparaffin that has one or more hydrogen atoms on the α -carbon atom can couple with a diazonium salt. A mixture of products is obtained from the interaction of nitromethane and benzenediazonium chloride.¹⁰⁴ Nitroformaldehyde phenylhydrazone (L) is obtained when the reaction is carried out in dilute hydrochloric acid.¹⁰⁵ However, *N,N'*-diphenyl-*C*-nitroformazan (LI) is the principal product in weakly alkaline solution or even at *pH* 4.5.²⁰ In alkaline solution, a third molecule of diazonium salt causes replacement of the nitro group by a phenyl group.



The product isolated from the reaction of nitromethane with other diazonium salts usually has been the nitroformazan derivative.^{20,106}

Other primary nitroparaffins couple only once to give hydrazones of β -nitroaldehydes, and secondary nitroparaffins yield azo compounds.



¹⁰³ Claus, *Ber.*, **45**, 747 (1912).

¹⁰⁴ Bamberger, Schmidt, and Levinstein, *Ber.*, **33**, 2043 (1900).

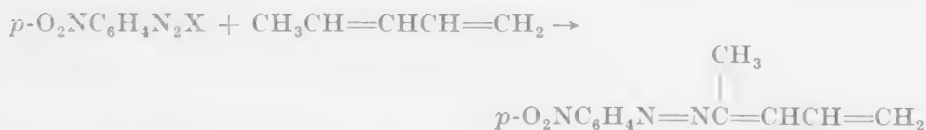
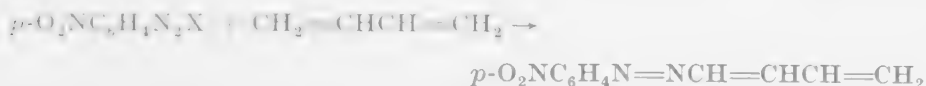
¹⁰⁵ Bamberger, *Ber.*, **27**, 155 (1894).

¹⁰⁶ Hubbard and Scott, *J. Am. Chem. Soc.*, **65**, 2390 (1943).

Hydrocarbons

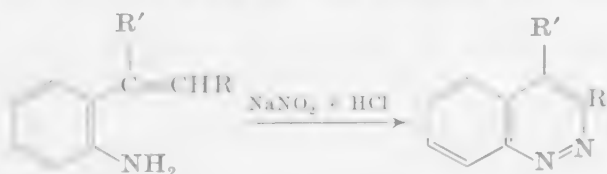
In this section are included aliphatic hydrocarbons and compounds containing a reactive hydrocarbon radical bonded to an aromatic ring.

A number of aliphatic hydrocarbons with conjugated double bonds form monoazo derivatives with diazonium salts.^{115,116} The yields are usually low, even with the reactive diazonium salts prepared from *p*-nitroaniline or 2,4-dinitroaniline. Coupling occurs at the carbon atom having the highest electron density. In 1,3-butadiene this is carbon 1, whereas in 1,3-pentadiene it is carbon 4.



The only two monoolefins that couple are 2-methylpropene and 2-methyl-2-butene.¹¹⁶ The cyclic hydrocarbons cyclopentadiene^{117,118} and indene¹¹⁸ also give monoazo derivatives.

The coupling of α,α -diarylethylenes with diazonium salts was discussed above (p. 4). A similar reaction, which occurs intramolecularly when *o*-aminophenylethylenes are diazotized, is the Widman-Stoermer synthesis of cinnolines.¹¹⁹⁻¹²¹ The scope of this reaction has been studied by



Simpson and Stephenson,¹²² and by Schofield,¹²³ who have found that good yields of the cinnoline are obtained when R' is methyl or aryl and R is hydrogen. Cinnoline formation also occurs when both R and R' are aromatic. However, if R' is hydrogen or carboxyl and R is aromatic,

¹¹⁵ Meyer, *Ber.*, **52**, 1468 (1919).

¹¹⁶ Terent'ev and Demidova, *J. Gen. Chem. U.S.S.R.*, **7**, 2464 (1937) [*C. A.*, **32**, 2094 (1938)].

¹¹⁷ Eibner and Laue, *Ber.*, **39**, 2022 (1906).

¹¹⁸ Terent'ev and Gomborg, *J. Gen. Chem. U.S.S.R.*, **8**, 662 (1938) [*C. A.*, **33**, 1285 (1939)].

¹¹⁹ Widman, *Ber.*, **17**, 722 (1884).

¹²⁰ Stoermer and Fincke, *Ber.*, **42**, 3115 (1909).

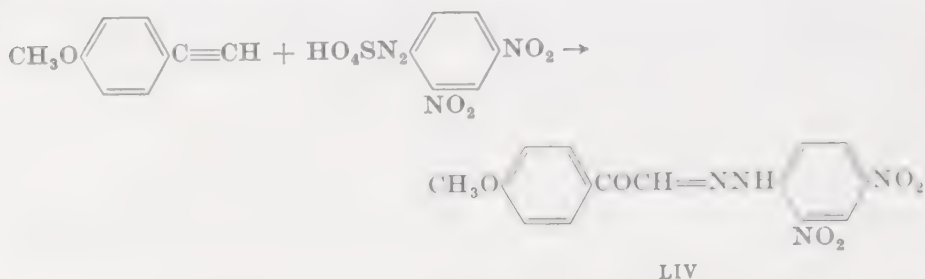
¹²¹ Stoermer and Gaus, *Ber.*, **45**, 3104 (1912).

¹²² Simpson and Stephenson, *J. Chem. Soc.*, **1942**, 353.

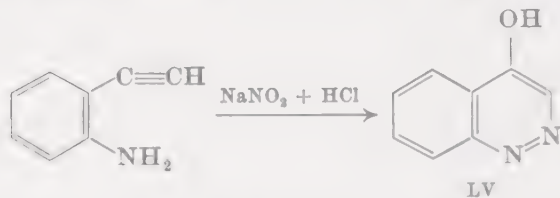
¹²³ Schofield, *J. Chem. Soc.*, **1949**, 2408.

the diazotized amine undergoes the Pschorr reaction to yield a phenanthrene derivative.

When *p*-methoxyphenylacetylene couples with 2,4-dinitrobenzene-diazonium sulfate, a 69% yield of α -*p*-anisylglyoxal β -2,4-dinitrophenylhydrazone (LIV) is formed.¹²⁴ This reaction is similar to the synthesis



of 4-hydroxycinnoline (LV) from diazotized *o*-aminophenylacetylene.¹²⁵ In each case the elements of a hydroxyl group, derived from the aqueous reaction medium, appear in the product. This ring closure was used first



by von Richter to make 4-hydroxycinnoline-3-carboxylic acid from *o*-aminophenylpropionic acid.¹²⁶ Recent examples of the reaction have employed nuclear substituted *o*-aminophenylacetylenes, *o*-aminophenylpropionic acids, and *o*-aminodiphenylacetylene.^{23,125}

Although styrene does not react with 2,4-dinitrobenzenediazonium sulfate, *p*-methoxystyrene (LVI) is converted to the 2,4-dinitrophenylhydrazone of anisaldehyde by this reagent.¹²⁴ The same product is obtained when the dry diazonium salt is added to an alcoholic solution of anethole (LVII).¹²⁷ Acetaldehyde is eliminated in the second reaction. Other compounds that show a similar coupling with the loss of acetaldehyde are isoeugenol,¹²⁸ isosafrole,¹²⁷ isocaprole,¹²⁷ and *p*-propenyl-dimethylaniline.¹²⁹ It is even possible to obtain a 60% yield of *p*-hydroxybenzaldehyde *p*-nitrophenylhydrazone from the action of dry

¹²³ Ainley and Robinson, *J. Chem. Soc.*, **1937**, 369.

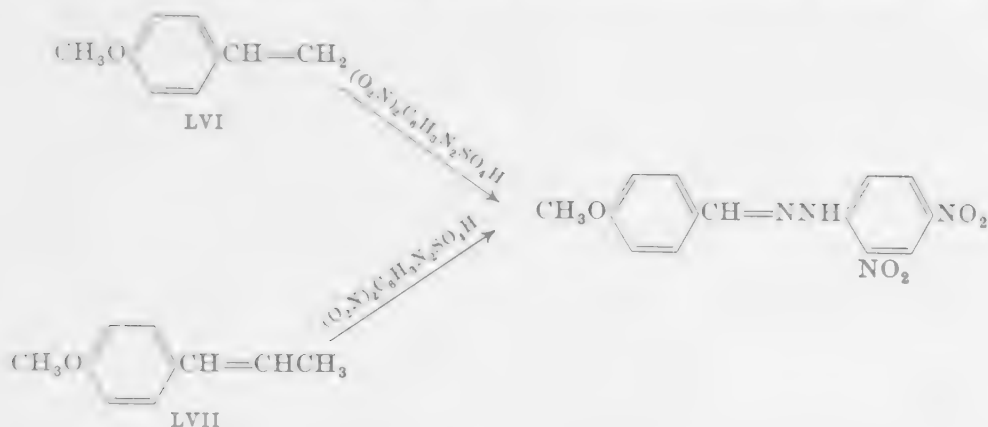
¹²⁵ Schofield and Simpson, *J. Chem. Soc.*, **1945**, 512.

¹²⁶ von Richter, *Ber.*, **16**, 677 (1883).

¹²⁷ Quilico and Freri, *Gazz. chim. ital.*, **58**, 380 (1928).

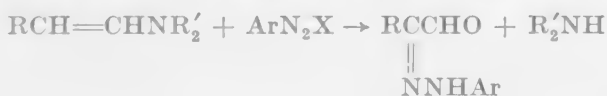
¹²⁸ Quilico and Fleischner, *Gazz. chim. ital.*, **59**, 39 (1929).

¹²⁹ Quilico and Freri, *Gazz. chim. ital.*, **60**, 606 (1930).

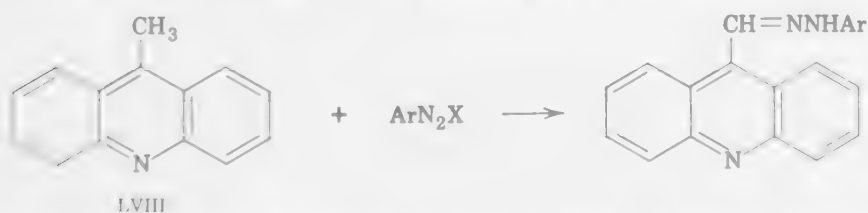


p-nitrobenzenediazonium sulfate on an alcoholic solution of *p*-propenylphenol.¹³⁰

The reaction of an α,β -unsaturated tertiary amine with a diazonium salt resembles that of an unsaturated hydrocarbon. Coupling occurs at the β -carbon atom, and the amino group is eliminated. If there is a hydrogen substituent on the β -carbon, the β -arylhydrazone of a glyoxal is obtained. However, if there is no hydrogen attached to the β -carbon, the enamine is cleaved to give the hydrazone of a ketone.^{130a}



Methyl groups in the α or γ positions of some heterocyclic compounds combine with diazonium salts. For example, 9-methylacridine (LVIII)



has been coupled with a number of salts to give the arylhydrazones of acridine 9-carboxaldehyde.¹³¹ If the hetero atom is converted into the onium salt, the activity of the methyl group is increased.¹³² 2,3,3-Trimethylindolenine is an exception, for the base is more reactive than

¹³⁰ Quilico and Freri, *Gazz. chim. ital.*, **59**, 600 (1929).

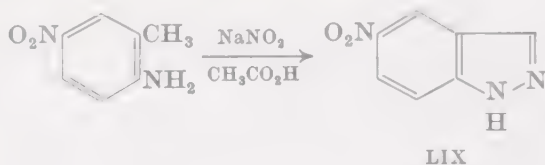
^{130a} Cray, Quayle, and Lester, *J. Am. Chem. Soc.*, **78**, 5584 (1956).

¹³¹ Porai-Koshits and Kharkharov, *Bull. acad. sci. U.R.S.S. classe sci. chim.*, **1944**, 143 [*C. A.*, **39**, 1631 (1945)].

¹³² Kharkharov, *J. Gen. Chem. U.S.S.R.*, **23**, 1175-1181 (1953) [*C. A.*, **47**, 12290 (1953)].

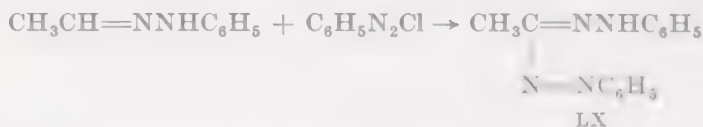
its salts.^{132a} Heterocyclic compounds that have been studied include α -picoline,¹³² 9-methylxanthylum perchlorate,¹⁴ 9-methylthioxanthylum perchlorate,¹⁴ 2,3-dimethylbenzothiazolium salts,^{132a-7} quinaldinium salts,^{132g,133,134} and 2,3,3-trimethylindolenium salts.^{132a,133,135} The methyl group of 2,4,6-trinitrotoluene also reacts with *p*-nitrobenzenediazonium chloride in pyridine solution.¹³² In addition, the ethylidene group in 1-phenyl-3-methyl-4-ethylidene-5-pyrazolones shows a reactivity toward diazonium salts.^{135a}

A ring closure which involves a methyl group is the indazole synthesis via intramolecular coupling of diazotized *o*-toluidines. Although *o*-toluidine gives only a small yield of indazole,¹³⁶ many substituted *o*-toluidines give excellent yields of substituted indazoles.¹³⁷ The preparation of 5-nitroindazole (LIX) is typical.¹³⁸



Hydrazones

Arylhydrazones of many aliphatic and aromatic aldehydes have been coupled with diazonium salts to yield formazan derivatives. An example is the production of *N,N'*-diphenyl-C-methylformazan (LX) in 88% yield from acetaldehyde phenylhydrazone.¹³⁹ The fact that the reaction does



^{132a} Gault and Wahl, *Compt. rend.*, **240**, 983 (1955).

^{132b} Wahl and Le Bris, *Bull. soc. chim. France*, **1954**, 587.

^{132c} Wahl and Le Bris, *Compt. rend.*, **234**, 631 (1952).

^{132d} Le Bris and Wahl, *Bull. soc. chim. France*, **1954**, 248.

^{132e} Wahl, *Bull. soc. chim. France*, **1954**, 251.

^{132f} Porai-Koshits and Muravich, *J. Gen. Chem. U.S.S.R.*, **23**, 1583-1593 (1953) (*ibid.*, **4**, 48 (1954)).

^{132g} Wizinger and Atakan, *Helv. Chim. Acta*, **39**, 1330 (1956).

¹³³ König, *Ber.*, **57**, 891 (1921).

¹³⁴ König, *Ber.*, **56**, 1543 (1923).

¹³⁵ König and Muller, *Ber.*, **57**, 144 (1924).

^{135a} Porai-Koshits and Dinaburg, *J. Gen. Chem. U.S.S.R.*, **24**, 2208 (1954) (*ibid.*, **4**, 50 (1955)).

¹³⁶ Bamberger, *Ann.*, **305**, 289 (1899).

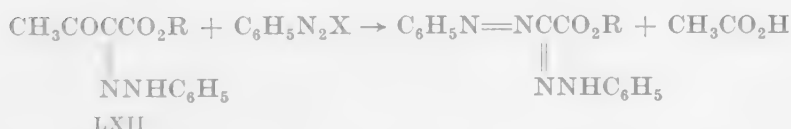
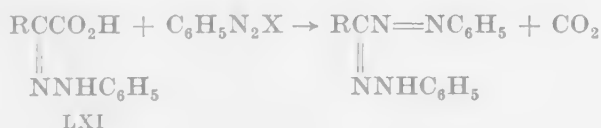
¹³⁷ Nölting, *Ber.*, **37**, 2556 (1904).

¹³⁸ Fieser and Peterson, *Org. Syntheses, Coll. Vol. III*, 600 (1955).

¹³⁹ Bamberger and Billeter, *Helv. Chim. Acta*, **14**, 219 (1931).

not take place with secondary hydrazones was mentioned on p. 5.¹⁹ The reaction of the phenylhydrazones of 2-hydroxy-1-nitroaldehydes with degradation of the molecule to give an aldehyde and nitroformazan was mentioned under the discussion of nitro compounds. The formazans obtained from phenylhydrazones of aldoses have proved to be useful derivatives of these sugars.^{139a-f}

The hydrazones of only two kinds of ketones have been converted into formazans. These are the arylhydrazones of α -keto acids (LXI)^{19,140-145} and the α -arylhydrazones of α,β -diketobutyric esters (LXII).^{19,60,142,146} With the first type coupling causes decarboxylation, and with the second type an acetyl group is replaced. These eliminations are very similar to the Japp-Klingemann reaction.



Reports of the isolation of two isomeric forms of unsymmetrical formazans^{18,147} have been shown to be erroneous.¹⁴⁸⁻¹⁵⁰ The unsymmetrical formazans obtained by both possible routes (A and B) are identical. The isolation of the same compound from both of these reactions has been rationalized by the assumption that the product has the structure of the resonance hybrid of the chelated forms LXIII.^{148,149}

^{139a} Mester, *J. Am. Chem. Soc.*, **77**, 4301 (1955).

^{139b} Mester and Major, *J. Am. Chem. Soc.*, **78**, 1403 (1956).

^{139c} Zemplén and Mester, *Acta Chim. Acad. Sci. Hung.*, **2**, 9 (1952) [*C. A.*, **48**, 1966 (1954)].

^{139d} Mester and Major, *J. Am. Chem. Soc.*, **77**, 4305 (1955).

^{139e} Mester and Major, *J. Am. Chem. Soc.*, **77**, 4297 (1955).

^{139f} Zemplén, Mester, Messner, and Eckhart, *Acta Chim. Acad. Sci. Hung.*, **2**, 25 (1952) [*C. A.*, **48**, 1966 (1954)].

¹⁴⁰ Bamberger, *Ber.*, **25**, 3547 (1892).

¹⁴¹ Wedekind and Stauwe, *Ber.*, **31**, 1746 (1898).

¹⁴² Bamberger and de Gruyter, *J. prakt. Chem.*, [2], **64**, 222 (1901).

¹⁴³ Busch and von Beust, *Ber.*, **58**, 442 (1925).

¹⁴⁴ Ragno and Bruno, *Gazz. chim. ital.*, **76**, 485 (1946).

¹⁴⁵ Fusco and Romani, *Gazz. chim. ital.*, **78**, 342 (1948).

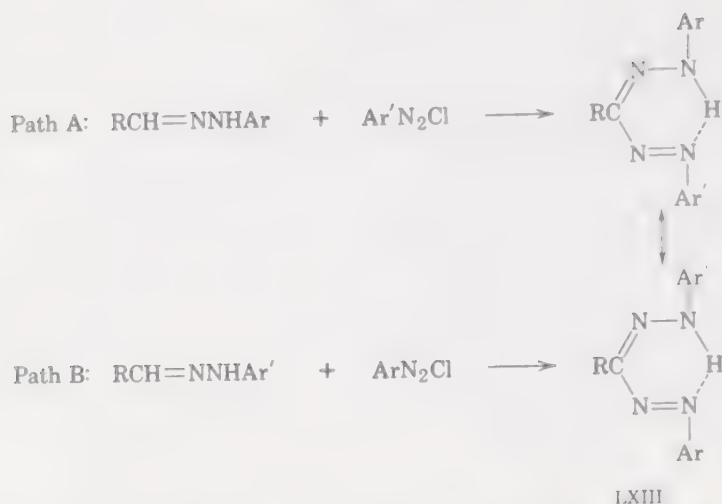
¹⁴⁶ Lapworth, *J. Chem. Soc.*, **83**, 1114 (1903).

¹⁴⁷ Fichter and Schiess, *Ber.*, **33**, 747 (1900).

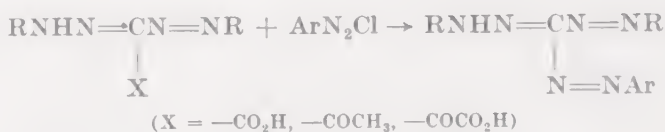
¹⁴⁸ Kuhn and Jerchel, *Ber.*, **74**, 941 (1941).

¹⁴⁹ Hunter and Roberts, *J. Chem. Soc.*, **1941**, 820.

¹⁵⁰ Hauriger, Jerchel, and Kuhn, *Chem. Ber.*, **84**, 651 (1951).



A formazan in which the carbon is joined to a carboxyl,^{19,70,140,151,152} acetyl,^{52,142} or oxalyl group¹⁵³ loses that group when it couples with another molecule of diazonium salt.



Heterocyclic Compounds

In this section are included those heterocyclic compounds that have a methylene group with a carbonyl group adjacent to it in the ring. These reactants can exist in the tautomeric enolic form as well.

Of the compounds in this group, the 5-pyrazolones have been investigated most extensively because of the successful use of their azo derivatives as dyes. No attempt has been made to include here all of the pyrazolones that appear in the patent literature. The early patents in this field have been reviewed by Roux and Martinet,¹⁵⁴ and some of the more recent ones have been discussed by Venkataraman.¹⁵⁵ The 1-aryl-3-methyl-5-pyrazolones (LXIV) have been used most frequently in the preparation of dyes. Pyrazolones with a methyl group in the

¹⁵¹ Bamberger and Wheelwright, *Ber.*, **25**, 3201 (1892).

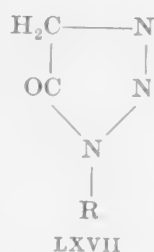
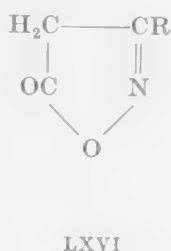
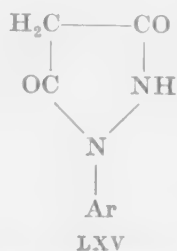
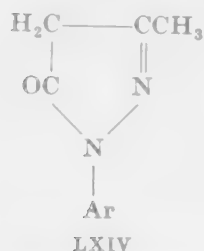
¹⁵² Chatterway and Lye, *Proc. Roy. Soc. London*, **A137**, 489 (1932); *ibid.*, **26**, 555 (1932).

¹⁵³ Bamberger and Muller, *J. prakt. Chem.*, [2], **64**, 199 (1901).

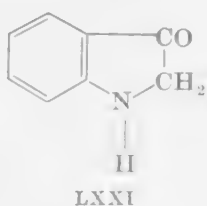
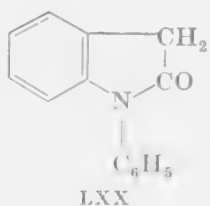
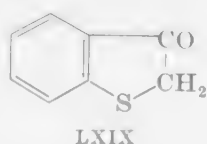
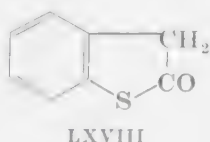
¹⁵⁴ Roux and Martinet, *Rev. gén. mat. color.*, **27**, 115-120, 134-139, 152-155 (1923), **28**, 13-14, 74-77 (1924).

¹⁵⁵ Venkataraman, *The Chemistry of Synthetic Dyes*, Chapter XVIII, Academic Press, New York, 1952.

4-position fail to react with diazonium salts.¹⁵⁶ On the other hand, pyrazolones with an ethylene, isopropylidene, or benzal group in the 4-position couple with the loss of that substituent.^{157,158}



Other heterocycles that contain a methylene group active toward diazonium salts include 3,5-pyrazolidinediones (LXVIII), 5-isoxazolones (LXIX), 1,2,3-triazole-5-ones (LXXVII), 2(3)-thianaphthenone (LXXVIII), 3(2)-thianaphthenone (LXXIX), 1-phenyloxindole (LXXX), indoxyl (LXXXI), barbituric acid, and homophthalimide.



SYNTHETIC APPLICATIONS

The reactions of diazonium salts with many aliphatic compounds have been used only to prepare derivatives for purposes of characterization. The adaptability of the reaction to large-scale syntheses is evident from the quantities of dyes that have been produced from β -ketoamides and 5-pyrazolones. The Pschorr synthesis and related diazonium ring closure reactions are discussed in Chapter 7 of *Organic Reactions*, Volume 9.

Cinnolines

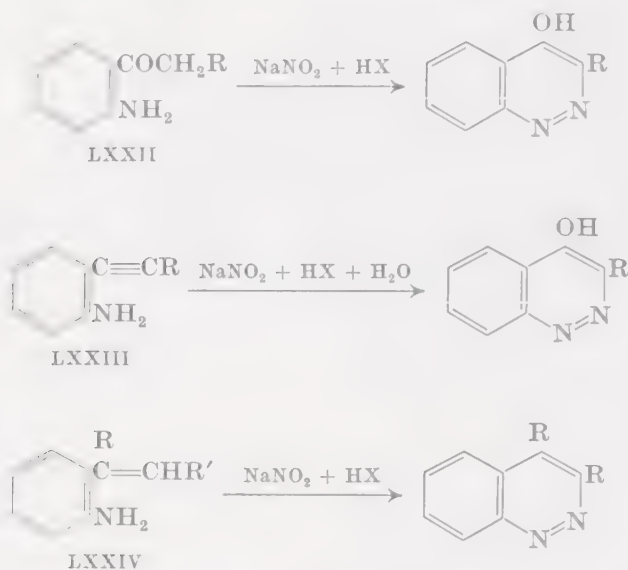
All of the general methods for the preparation of cinnolines employ the intramolecular coupling of a diazonium salt with some aliphatic substituent

¹⁵⁶ Verkade and Dhont, *Rec. trav. chim.*, **64**, 165 (1945).

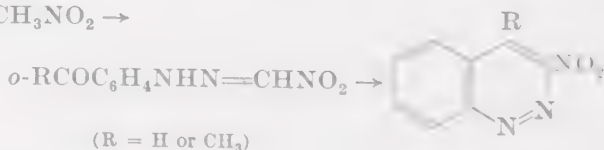
¹⁵⁷ Stolz, *Ber.*, **28**, 623 (1895).

¹⁵⁸ Sawdey, Ruoff, and Vittum, *J. Am. Chem. Soc.*, **72**, 4947 (1950).

in the ortho position. The Borsche synthesis¹⁵⁹ from *o*-aminophenyl ketones (LXXII) has been used to prepare a variety of 3-, 5-, 6-, 7-, and 8-substituted 4-hydroxycinnolines.^{22,24,37-41,159,167a,c} The method of von Richter¹²⁶ based upon *o*-aminophenylacetylenes (LXXIII) produces 3-carboxy- or 3-phenyl-4-hydroxycinnolines.^{23,125} Cinnolines with alkyl or aryl substituents in the 4 position are obtained by the Widman-Stoermer synthesis from *o*-aminoarylethylenes (LXXIV).^{119-121,167d}



3-Nitrocinnolines have been synthesized by coupling diazotized *o*-aminobenzaldehyde or *o*-aminoacetophenone with nitromethane and cyclizing the resulting arylhydrazone of nitroformaldehyde.^{167d}



¹⁵⁹ Borsche and Herbert, *Ann.*, **546**, 293 (1941).

¹⁶⁰ Koelsch, *J. Org. Chem.*, **8**, 295 (1943).

¹⁶¹ Atkinson and Simpson, *J. Chem. Soc.*, **1947**, 232.

¹⁶² Keneford and Simpson, *J. Chem. Soc.*, **1947**, 227.

¹⁶³ Simpson, *J. Chem. Soc.*, **1947**, 237.

¹⁶⁴ Keneford, Morley, and Simpson, *J. Chem. Soc.*, **1948**, 1702.

¹⁶⁵ Schofield and Theobald, *J. Chem. Soc.*, **1949**, 2404.

¹⁶⁶ McIntyre and Simpson, *J. Chem. Soc.*, **1952**, 2606.

^{167a} Alford, Irving, Marsh, and Schofield, *J. Chem. Soc.*, **1952**, 3009.

^{167b} Castle and Kruse, *J. Org. Chem.*, **17**, 1571 (1952).

^{167c} Albert and Hampton, *J. Chem. Soc.*, **1952**, 4985.

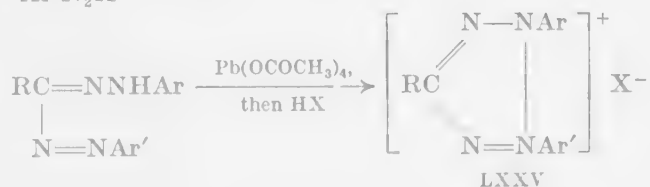
^{167d} Baumgarten and DeBrunner, *J. Am. Chem. Soc.*, **76**, 3489 (1954).

Indazoles

Intramolecular coupling of diazotized *o*-toluidines has been used to prepare a number of substituted indazoles. This method is best for the synthesis of nitroindazoles (LIX). A good yield of indazole-3-carboxylic acid is obtained via the nitrile XLII from *o*-aminophenylacetonitrile.^{95b,168} A method for the preparation of 1-aryl-6-nitroindazoles (XXXVIII) employs the reaction of a diazonium salt with methyl 2,4-dinitrophenylacetate. When the resulting hydrazone is treated with alkali, it undergoes ring closure with the loss of one nitro group.⁷⁸⁻⁸⁰

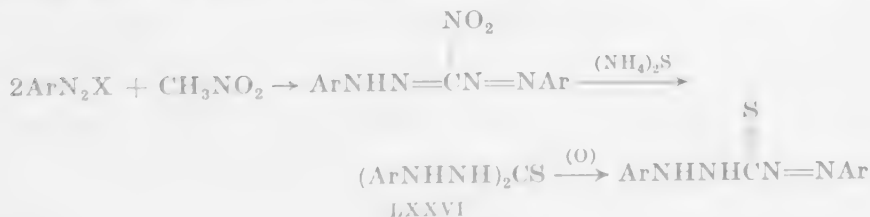
Tetrazolium Salts

When a formazan is oxidized with lead tetraacetate, a tetrazolium salt (LXXV) is produced. The formazans in turn are synthesized by coupling a diazonium salt with an arylhydrazone. This general route appears to be the only good one for the preparation of tetrazolium salts. The preparations and uses of formazans and tetrazolium salts have been reviewed by Ried¹⁶⁹ and by Nineham.¹⁶⁹



Thiocarbazonates

The first step in the synthesis of thiocarbazonates utilizes the reaction of nitromethane with two equivalents of diazonium salt.^{20,106,170} The resulting nitroformazan is reduced by ammonium sulfide to the thiocarbazide LXXVI which is oxidized readily to the thiocarbazonate.

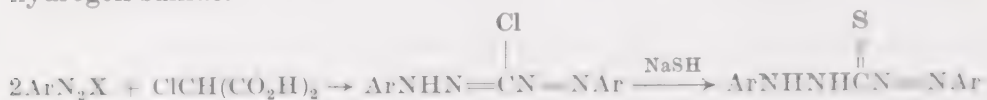


¹⁶⁸ Rousseau and Lindwall, *J. Am. Chem. Soc.*, **72**, 3047 (1950).

¹⁶⁹ Ried, *Angew. Chem.*, **64**, 391 (1952); Nineham, *Chem. Revs.*, **55**, 355 (1955).

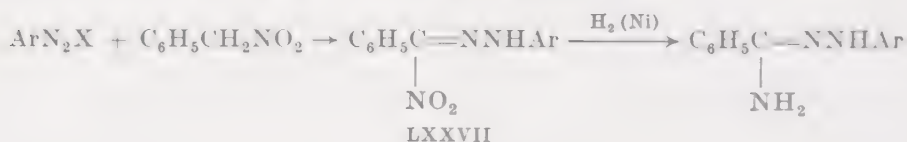
¹⁷⁰ Oesper and Klingenberg, *J. Org. Chem.*, **13**, 309 (1948).

A related synthesis starts with chloromalonic acid.^{170a} In this method the chloroformazan is converted directly to the thiocarbazone by sodium hydrogen sulfide.



Amidrazones*

The catalytic reduction of arylhydrazones of α -nitrobenzaldehyde (LXXVII) offers a convenient synthesis of amidrazones.¹⁷¹ Coupling of a diazonium salt with phenylnitromethane furnishes the required hydrazone. Ponzio obtained the amidrazones from the reaction of the α -nitrobenzaldehyde arylhydrazone with ammonia.¹⁷²



Amines

The only report of the use of the coupling reaction to introduce the amino group into active methylene compounds appears in the patent literature.¹⁷³ In this method the phenylhydrazones obtained from ethyl acetoacetate, ethyl cyanoacetate, or acetylacetone and benzenediazonium chloride were reduced with zinc and acetic acid to give the α -acetamido compounds.

EXPERIMENTAL CONDITIONS

Diazonium salts react with so many different types of aliphatic compounds that it is difficult to make generalizations about experimental conditions. However, the following summary may serve as a useful guide.

Diazonium Salts

For the diazotization of most arylamines a solution of sodium nitrite is added to a cold solution of the arylamine in aqueous mineral acid

^{170a} Irving and Bell, *J. Chem. Soc.*, **1953**, 3538.

* Amidrazones may be represented by the general formula $\text{RC}_6\text{H}_4\text{NH}_2=\text{NNHR}$. They are indexed in *Chemical Abstracts* as the hydrazones of amides.

¹⁷¹ Jerchel and Fischer, *Ann.*, **574**, 85 (1951).

¹⁷² Ponzio, *Gazz. chim. ital.*, **40**, I, 312 (1910).

¹⁷³ Pfister and Tishler, U.S. pat. 2,489,927 [*C. A.*, **44**, 2552 (1950)].

For weakly basic amines or amino acids it is necessary to employ special techniques. These methods have been reviewed by Saunders.¹⁷⁴

Solvents

These reactions have been conducted most frequently in cold dilute aqueous solutions buffered with sodium acetate. Alcohol or occasionally pyridine or acetic acid is added if the reactants are too insoluble in water. Special reactions that have been carried out under anhydrous conditions were discussed under Scope and Limitations, pp. 22–23.

pH

Reaction can occur between a diazonium salt and many active methylene compounds over a wide pH range. Coupling in dilute hydrochloric acid^{66,82} or in dilute sodium hydroxide¹⁷⁵ is usually less satisfactory than coupling in the presence of sodium carbonate or sodium acetate buffers.⁸² The general practice is to use a large excess of sodium acetate.

Hünig and Boes made an extensive study of the relative reactivity of various methylene compounds, XCH_2Y , toward *p*-nitrobenzenediazonium fluoroborate over a pH range from 2 to 10.^{19c} The lowest pH at which a compound would couple was taken as an indication of its reactivity. The substituents X and Y arranged in the order of their decreasing ability to activate were: NO_2 , CHO, $COCH_3$, CN, $CO_2C_2H_5$, $CONH_2$, CO_2CH_3 , $SO_2C_2H_5$, $SOCH_3$, C_6H_5 . Only the most active compounds coupled in acidic solution, and the least active failed to couple even in alkaline solution.

In the intramolecular coupling reactions used to prepare cinnolines or indazoles a strongly acidic solution is employed. This promotes the coupling reaction and decreases the competing decomposition of the diazonium salt to the phenol. Acidic solutions are used in the reactions of diazonium salts with hydrocarbons for similar reasons.

The optimum reaction conditions for nitro compounds vary considerably. It has been customary to employ an aqueous solution of the sodium salt of the *aci*-nitro compound. The coupling of nitromethane, on the other hand, proceeds well at a pH of 4.5.²⁰ With nitro alcohols a fairly high pH is required. The reaction of 2-nitro-1-butanol with *p*-chlorobenzenediazonium chloride does not occur below pH 10.8, and best yields are obtained at pH 13.9.¹⁰⁸ It has been reported that solutions

¹⁷⁴ Saunders, *The Aromatic Diazo-Compounds*, Edward Arnold & Co., London, 1949.

¹⁷⁵ von Rothenburg, *Ber.*, **27**, 685 (1894).

of 1-N-morpholino-2-nitropropane between pH 7 and 10 *explodes with great violence during the coupling process*.^{176a}

Reactant Ratios

Equivalent amounts of reactant and diazonium salt are most commonly employed. Excess diazonium salt should be avoided since the product is frequently a hydrazone which can couple with another molecule of the salt to produce a formazan derivative. The latter reaction is favored by a strongly alkaline solution.

Time of the Reaction

Since most of the coupling reactions are rapid, the product can be isolated soon after the diazonium salt has been added. However, the reactions that involve intramolecular coupling require more time for completion. In the preparation of indazoles, the diazotized *o*-toluidine derivative may be left for several days to effect the ring closure.^{137,138} Likewise, the formation of cinnolines is often slow.^{23,38,39,164,167a-c} For certain cinnolines this cyclization is accelerated by the use of a warm, strongly acidic reaction medium.^{37,40}

EXPERIMENTAL PROCEDURES

The preparation of pyruvaldehyde 1-phenylhydrazone from acetoacetic acid and benzenediazonium chloride in 73-82% yield is described in *Organic Syntheses*.⁵⁵

Directions for the preparation of 5-nitroindazole in yields of 72-80% by the intramolecular coupling of diazotized 2-methyl-4-nitroaniline are given in *Organic Syntheses*.¹³⁸

Ethyl α,β -Dioxobutyrate α -Phenylhydrazone.²⁸⁵ A solution of 73 g. (1.06 moles) of sodium nitrite in 250 ml. of water is added slowly below the surface of a cold, well-stirred solution of 93 g. (1.0 mole) of aniline in 500 ml. of 5 *N* hydrochloric acid. The temperature of the solution is kept at 0-5° during the addition. After ten minutes the solution is made alkaline to Congo red by the addition of saturated sodium acetate solution. The diazonium solution is added slowly with stirring in a cold slurry of 130 g. (1.0 mole) of ethyl acetoacetate, 120 g. (1.46 moles) of sodium acetate, and 200 ml. of water in 750 ml. of ethanol. The temperature is held below 10° during the addition. The mixture is stirred for a further thirty minutes at 5-10° and for ninety minutes at

²⁸⁵ Van Biema and Degering, *J. Am. Chem. Soc.*, **66**, 1514 (1944).

room temperature. One liter of water is added before the yellow solid is collected. The yield is 229 g. (98%) of product that melts at about 70°, but whose melting point varies markedly with the rate of heating.

Ethyl Cyanoglyoxalate *m*-Chlorophenylhydrazone.^{74a} A solution of 38 g. (0.30 mole) of *m*-chloroaniline in 85 ml. of concentrated hydrochloric acid and 300 ml. of water is cooled to 5° with stirring. Diazotization is effected by the slow addition of a solution of 23 g. (0.33 mole) of sodium nitrite in 50 ml. of water while the temperature is held below 5°. The solution is stirred with activated carbon for an additional ten minutes (temperature below 10°) and filtered. The filtrate is added dropwise during one hour to a well-stirred mixture of 33.9 g. (0.30 mole) of ethyl cyanoacetate in 300 ml. of water at 5–10°. Sodium carbonate (100 g.) is added in small portions to keep the mixture alkaline to litmus. The mixture is extracted with ether until the extracts are no longer colored. The combined ether extracts are dried over magnesium sulfate and concentrated. The residue is crystallized from ethanol to give 73 g. (97%) of pale-orange crystals, m.p. 89–90°.

By the same procedure, diethyl malonate is converted into diethyl mesoxalate *m*-chlorophenylhydrazone in 78% yield. Likewise, ethyl acetoacetate is converted into ethyl α,β -dioxobutyrate α -*m*-chlorophenylhydrazone in 78% yield.

1-Nitro-1-*p*-chlorophenylhydrazonoethane.^{176b} To a cold solution of 8.4 g. (0.066 mole) of *p*-chloroaniline in 17 ml. of concentrated hydrochloric acid and 200 ml. of water is added slowly with stirring a solution of 4.7 g. (0.068 mole) of sodium nitrite in 50 ml. of water. The temperature is held at 0–5° during the addition. After ten minutes, the solution is diluted with 1.7 l. of cold water, and 30 g. of sodium acetate trihydrate is added. Meanwhile, 5 g. (0.066 mole) of nitroethane is dissolved in an ice-cold solution of 2.6 g. of sodium hydroxide in 20 ml. of water. The nitroethane solution is added dropwise during ten minutes to a well-stirred solution of the diazonium salt. The temperature of the mixture is held at 5–10° during the addition. After thirty minutes the orange solid is collected. The yield of product melting at 116–118° is 14 g. (100%). Recrystallization from ethanol gives orange-yellow crystals which decompose at 126–127° when placed in a bath preheated to 120°.

1-(*p*-Nitrophenylazo)-2,3-dimethyl-1,3-butadiene.¹¹⁵ A warm solution of 13.8 g. (0.10 mole) of *p*-nitroaniline in 25 ml. of concentrated hydrochloric acid and 25 ml. of water is poured onto 100 g. of ice. The mixture is stirred with a solution of 7 g. (0.10 mole) of sodium nitrite in 50 ml. of water until the solid dissolves. The solution is diluted with 100 ml. of water and shaken for two hours with 9 g. (0.11 mole) of

^{176b} Barabarger and Grob, *Ber.*, **35**, 67 (1902).

2,3-dimethyl-1,3-butadiene.^{176c} The solid is collected and dried to give 12 g. (47%) of product. After recrystallization from acetic acid containing some charcoal, the product melts at 177°.

N,N'-Diphenyl-C-methylformazan.¹³⁹ Aqueous benzenediazonium chloride is prepared by the addition of a solution of 7 g. (0.1 mole) of sodium nitrite in 15 ml. of water to 9.3 g. (0.1 mole) of aniline dissolved in 25 ml. of concentrated hydrochloric acid and 25 ml. of water. A warm solution of 13.4 g. (0.1 mole) of acetaldehyde phenylhydrazone (α or β form) in 100 ml. of ethanol is mixed with a warm solution of 30 g. of sodium acetate trihydrate in 150 ml. of ethanol. The mixture is cooled to 5° with vigorous stirring before the diazonium salt solution is added dropwise. The product separates as an oil which soon solidifies. The solid is collected and washed with a little cold ethanol to give 21 g. (88%) of N,N'-diphenyl-C-methylformazan, which melts at 123°. Recrystallization from ethanol raises the melting point to 125°.

4-Hydroxy-3-methylcinnoline.⁴⁰ To a cold solution of 45.5 g. (0.31 mole) of *o*-aminopropiophenone in 1.2 l. of concentrated hydrochloric acid is added slowly with stirring 23 g. (0.33 mole) of sodium nitrite in 30 ml. of water. The temperature is kept at 5–10° during the addition. The solution is filtered, and 4 l. of concentrated hydrochloric acid is added to the filtrate. The reaction mixture is warmed at 60° for four hours before it is evaporated to a small volume under reduced pressure. An excess of saturated sodium acetate solution is added to precipitate the product, which is collected and dried to give 40.7 g. (83%) of almost pure 4-hydroxy-3-methylcinnoline. Recrystallization from 50% aqueous ethanol gives slender, silvery needles, m.p. 241–242°.

TABULAR SURVEY OF THE COUPLING OF DIAZONIUM SALTS WITH ALIPHATIC CARBON ATOMS

The tables include those reactions recorded prior to the January, 1956, issue of *Chemical Abstracts*. Some more recent examples are also given. The reactants within a table are in general listed in order of increasing size and complexity.

Where more than one reference is given for a single entry, the yield reported is taken from the first reference. Since yields are but infrequently reported, the omission of parenthesized figures in the product column indicates that no yield was reported:

^{176c} Allen and Bell, *Org. Syntheses Coll. Vol. 3*, 312 (1955).

TABLE I
COUPLING OF DIAZONIUM SALTS WITH KETONES

A. Monoketones		Substituent (s) in Aniline*	Product (Yield, %)	References
Ketone				
Acetone		—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{COCH}_3)_2\text{N}=\text{NC}_6\text{H}_5$	25
Chloroacetone		—	$\text{CH}_3\text{COC}(\text{Cl})=\text{NNHC}_6\text{H}_5$ (30)	28
		2-Methyl	$\text{CH}_3\text{COC}(\text{Cl})=\text{NNHC}_6\text{H}_4(\text{CH}_3-o)$ (25)	28
		4-Methyl	$\text{CH}_3\text{COC}(\text{Cl})=\text{NNHC}_6\text{H}_4(\text{CH}_3-p)$ (15)	28
α,α' -Dichloroacetone		—	$\text{ClCH}_2\text{COC}(\text{Cl})=\text{NNHC}_6\text{H}_5$	177
		2-Methyl	$\text{ClCH}_2\text{COC}(\text{Cl})=\text{NNHC}_6\text{H}_4(\text{CH}_3-o)$	177
		4-Methyl	$\text{ClCH}_2\text{COC}(\text{Cl})=\text{NNHC}_6\text{H}_4(\text{CH}_3-p)$	177
α,α -Dichloroacetone		—	$(\text{C}_6\text{H}_5\text{N}=\text{N})_2\text{CCl}_2$	177
		4-Methyl	$(p\text{-CH}_3\text{C}_6\text{H}_4\text{N}=\text{N})_2(\text{Cl})_2$	177
<i>syn</i> -Tetrachloroacetone		—	$(\text{C}_6\text{H}_5\text{N}=\text{N})_2\text{CCl}_2$	177
Nitroacetone		4-Methyl	$(p\text{-CH}_3\text{C}_6\text{H}_4\text{N}=\text{N})_2\text{CCl}_2$	19c
Methylsulfonylacetone		4-Nitro	$\text{CH}_3\text{COC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2-p$ (59)	19c
1-Imino-2-pentanone		4-Nitro	$\text{CH}_3\text{SO}_2\text{C}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2-p$ (70)	178
Pyruvic acid		—	$\text{CH}_3\text{COC}(\text{N}=\text{NC}_6\text{H}_5)=\text{C}(\text{NH}_2)\text{CH}_3$	153, 227
Levulinic acid		—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{N}=\text{NC}_6\text{H}_5)\text{COCO}_2\text{H}$ (57)	179, 153, 180
γ -Oxopimelic acid		—	Diformazyl† (88)	153, 180
Cyclopentane-1,2-dione		—	Diformazyl†† (13-17)	33
α -Hydroxy- α -methyl- γ -oxoglutaric acid lactone		—	Cyclopentane-1,2,3-trione 1-phenylhydrazine	181
Ethyl 3-hydroxy-2,5-dioxo-3-cyclopentene-1-carboxylic acid		—	α -Hydroxy- α -methyl- β,γ -dioxoglutaric acid lactone β -phenylhydrazine	182
cyclopentene-1-carboxylic acid		—	Ethyl 3-hydroxy-2,5-dioxo-4-phenylazo-3-cyclopentene-1-carboxylic acid	29
2,4-Dinitrophenylacetone		—	1-(2,4-Dinitrophenyl)propane-1,2-dione 1-phenylhydrazine	183
2-Nitro-4-carbomethoxyphenylacetone		—	1-(2-Nitro-4-carbomethoxyphenyl)propane-1,2-dione	
			1-phenylhydrazine	

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

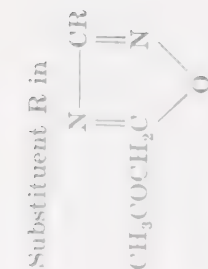
† The formula of the formazyl radical is $\text{C}_6\text{H}_5\text{NHN}=\text{CN}=\text{NC}_6\text{H}_5$.

†† Succinic acid was eliminated.

TABLE I—Continued

A. Monoketones—Continued

Substituents in Product,



Substituents in Aniline	R'	R	Yield, %	References
—	Phenyl	Phenyl	40	31, 32
2-Methyl	Phenyl	<i>p</i> -Tolyl	35	31, 32
4-Methyl	<i>o</i> -Tolyl	<i>p</i> -Tolyl	55	31, 32
2,4-Dimethyl	<i>p</i> -Tolyl	<i>p</i> -Tolyl	40	31, 32
2,5-Dimethyl	2,4-Dimethylphenyl	<i>p</i> -Tolyl	40	31, 32
2-Methoxy	2,5-Dimethylphenyl	<i>p</i> -Tolyl	—	32
3-Methoxy	<i>o</i> -Anisyl	<i>p</i> -Tolyl	35	31, 32
3-Chloro	<i>m</i> -Anisyl	<i>p</i> -Tolyl	35	31, 32
4-Chloro	<i>m</i> -Chlorophenyl	<i>p</i> -Tolyl	55	31, 32
2-Nitro	<i>p</i> -Chlorophenyl	<i>p</i> -Tolyl	30	31, 32
3-Nitro	<i>o</i> -Nitrophenyl	<i>p</i> -Tolyl	45	31, 32
4-Nitro	<i>m</i> -Nitrophenyl	<i>p</i> -Tolyl	20	31, 32
1-Dimethylamino	<i>p</i> -Nitrophenyl	<i>p</i> -Tolyl	20	31, 32
2-Carboxy	<i>p</i> -Dimethylaminophenyl	<i>p</i> -Tolyl	25	31, 32
4-Carboxy	<i>o</i> -Carboxyphenyl	<i>p</i> -Tolyl	50	31, 32
2-Naphthylamino	<i>p</i> -Carboxyphenyl	<i>p</i> -Tolyl	45	31, 32
β -Naphthylamino	α -Naphthyl	<i>p</i> -Tolyl	40	31, 32
4-Phenyl	β -Naphthyl	<i>p</i> -Tolyl	35	31, 32
4-Benzyl	<i>p</i> -Biphenyl	<i>p</i> -Tolyl	40	31, 32
3,3'-Dimethoxybenzidine	<i>p</i> -Benzylphenyl	<i>p</i> -Tolyl	45	31, 32
2-Methoxy	3,3'-Dimethoxybiphenylene	<i>p</i> -Tolyl	20	32
	Phenyl	<i>m</i> -Nitrophenyl	80	31, 32
	<i>o</i> -Anisyl	<i>m</i> -Nitrophenyl	50	31, 32

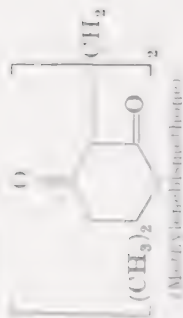
Ketone	Substituent(s) in Aniline	Product (Yield, %)	References
Acetylpyridinium bromide	—	$\text{CH}_3\text{COC}(\text{NC}_5\text{H}_5)=\text{N}^+\text{NC}_6\text{H}_5$ (84)	30
Phenacyl chloride	—	$\text{C}_6\text{H}_5\text{COC}(\text{Cl})=\text{N}^+\text{NC}_6\text{H}_5$	177
4-Carbomethoxy-3-methyl-5-phenyl- pyridolindanone	—	1-Carbomethoxy-3-methyl-5-phenyl-3-cyclohexene- 1,2-dione 2-phenylhydrazine	276
4-Carbomethoxy-3-methyl-5-phenyl-3- cyclohexenone	—	4-Carbomethoxy-3-methyl-5-phenyl-3-cyclohexene-1,2- dione 2-phenylhydrazine	276
4-Carbomethoxy-3,5-diphenyl-1,3-cyclo- hexadien-1-ol	—	4-Carbomethoxy-3,5-diphenyl-3-cyclohexene-1, 2-dione 2-phenylhydrazine	277
Phenyl 2,4-dinitrobenzyl ketone	—	$2,4-(\text{NO}_2)_2\text{C}_6\text{H}_3\text{COC}(\text{C}_6\text{H}_5)=\text{N}^+\text{NHC}_6\text{H}_5$ (quant.)	78
Phenacylpyridinium bromide	—	$\text{C}_6\text{H}_5\text{COC}(\text{NC}_5\text{H}_5)=\text{N}^+\text{NC}_6\text{H}_5$ (89)	30
	2-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{NC}_5\text{H}_5)=\text{N}^+\text{NC}_6\text{H}_4\text{NO}_2-o$	30
	3-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{NC}_5\text{H}_5)=\text{N}^+\text{NC}_6\text{H}_4\text{NO}_2-m$	30
	4-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{NC}_5\text{H}_5)=\text{N}^+\text{NC}_6\text{H}_4\text{NO}_2-p$	30
<i>p</i> -Bromophenacylpyridinium bromide	—	$p\text{-BrC}_6\text{H}_4\text{COC}(\text{NC}_5\text{H}_5)=\text{N}^+\text{NC}_6\text{H}_5$ (74)	184
5- <i>p</i> -Nitrophenacyl-3- <i>p</i> -tolyl- 1,2,4-oxadiazole	—	1-(3- <i>p</i> -Tolyl-1,2,4-oxadiazol-5-yl)-3- <i>p</i> -nitrophenyl- ethane-1,2-dione 1-phenylhydrazine (65)	32
	2-Methoxy	1-(3- <i>p</i> -Tolyl-1,2,4-oxadiazol-5-yl)-3- <i>p</i> -nitrophenyl- ethane-1,2-dione 1- <i>o</i> -methoxyphenylhydrazine (20)	32
	4-Nitro	1-(3- <i>p</i> -Tolyl-1,2,4-oxadiazol-5-yl)-3- <i>p</i> -nitrophenyl- ethane-1,2-dione 1- <i>p</i> -nitrophenylhydrazine (20)	32
Tropinone	—	2,4-Dioxotropinone diphenylhydrazine (80)	34
1-Ethoxalylindene	—	1-Phenylazo-1-ethoxalylindene	35
	3-Nitro	1- <i>m</i> -Nitrophenylazo-1-ethoxalylindene	35
	4-Nitro	1- <i>p</i> -Nitrophenylazo-1-ethoxalylindene	35

Note: References 177-480 are on pp. 136-142.

TABLE 1—Continued

A. Monoketones—Continued

Substituent(s) in Aniline	Product (Yield, %)	References
—	2,2'-Methylenebis-(3-hydroxy-5,5-dimethyl-6-phenylazo-2-cyclohexen-1-one) (quant.)	186, 185
2-Methyl	2,2'-Methylenebis-(3-hydroxy-5,5-dimethyl-6- <i>o</i> -tolylazo-2-cyclohexen-1-one)	185, 186
2,3-Dimethyl	2,2'-Methylenebis-[3-hydroxy-5,5-dimethyl-6-(2,3-xyllylazo)-2-cyclohexen-1-one]	185, 186
2,5-Dimethyl	2,2'-Methylenebis-(3-hydroxy-5,5-dimethyl-6- <i>p</i> -xyllylazo-2-cyclohexen-1-one)	185
4-Bromo	2,2'-Methylenebis-(3-hydroxy-5,5-dimethyl-6- <i>p</i> -bromophenylazo-2-cyclohexen-1-one)	185, 186
α -Naphthylamine	2,2'-Methylenebis-(3-hydroxy-5,5-dimethyl-6- α -naphthylazo-2-cyclohexen-1-one)	185, 186
β -Naphthylamine	2,2'-Methylenebis-(3-hydroxy-5,5-dimethyl-6- β -naphthylazo-2-cyclohexen-1-one)	185, 186
Benzidine	?	186
4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(C-2-quinolyl)formazan (79)	36a
4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(C-2-quinoxalyl)formazan (78)	36a
4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(C-2-quinazolyl)formazan	36a
4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(C-2-benzoxazolyl)formazan (76)	36a
4-Ethyl 2-quinolylpyruvate		
4-Ethyl 2-quinoxalylpyruvate		
4-Ethyl 2-quinazolylpyruvate		
4-Ethyl 2-benzoxazolylpyruvate		



Ethyl 2-benzothiazolylpyruvate	4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(2-benzothiazolyl)formazan (62)	36a
Ethyl 2-oxo-5-(2-benzothiazolyl)-4-pentenoate	4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(2-(2-benzothiazolyl)vinyl)formazan	36a
Ethyl 2-oxo-5-(2-benzothiazolyl)-4-pentenoate	4-Bromo	N,N'-Di-(<i>p</i> -bromophenyl)-(2-(2-benzothiazolyl)vinyl)formazan (46)	36a

<i>B. β-Ketodialdehydes</i>			
Substituent(s) in Aniline	Product (Yield, %)	References	
—	$\text{CH}_3\text{COC}(\text{CHO})=\text{NNHC}_6\text{H}_5$	49	
4-Nitro	$\text{CH}_3\text{COC}(\text{CHO})=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> (17)	19c	
—	$\text{C}_2\text{H}_5\text{COC}(\text{CHO})=\text{NNHC}_6\text{H}_5$	50	
—	$(\text{CH}_3)_2\text{C}=\text{CH}(\text{OC}(\text{CHO})=\text{NNHC}_6\text{H}_5)$	51	
—	$\text{C}_6\text{H}_5\text{COC}(\text{CHO})=\text{NNHC}_6\text{H}_5$	49	
—	$p\text{-CH}_3\text{C}_6\text{H}_4\text{COC}(\text{CHO})=\text{NNHC}_6\text{H}_5$	50*	
—	$p\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CHO})=\text{NNHC}_6\text{H}_5$	50	

<i>C. β-Diketones</i>			
Substituent(s) in Aniline*	Product (Yield, %)	References	
—	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_5$	12, 187, 188	
4-Methyl	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i> (92)	189	
4-Bromo	$(\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{Br})$ - <i>p</i>	190	
2,4-Dibromo	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_3\text{Br}_2$ -2,4	190	
2,4,6-Tribromo	$(\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_2\text{Br}_3)$ -2,4,6	190	
2-Nitro	$(\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2)$ - <i>o</i>	188, 190	

Note: References 177–480 are on pp. 136–142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

§ These compounds are named as derivatives of the hypothetical formazan, $\text{H}_2\text{NN}=\text{CHN}=\text{NH}$.

TABLE I—Continued

<i>C, p-Diketones—Continued</i>		References
Substituent(s) in Aniline*	Product (Yield, %)	
3-Nitro	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}m$	188
4-Nitro	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	188, 190
4-Methyl-3-nitro	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_3\text{CH}_3\text{-4-NO}_2\text{-3}$	189
4-Bromo-2-nitro	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_3\text{Br-4-NO}_2\text{-2}$	190
2,4-Dibromo-6-nitro- benzidine	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_2\text{Br}_2\text{-2,4-NO}_2\text{-6}$ 3,3'-(4,4'-Biphenylenedihydrazono)bis(pentane- 2,3,4-trione)	190 191, 192
3,3'-Dimethyl- benzidine	3,3'-(3,3'-Dimethyl-4,4'-biphenylenedihydrazono) bis(pentane-2,3,4-trione)	191, 192
3,3'-Dimethoxy- benzidine	3,3'-(3,3'-Dimethoxy-4,4'-biphenylenedihydrazono) bis(pentane-2,3,4-trione)	191, 192
4-(3-Methyl-5-phenyl- pyrazol-1-yl)	Pentane-2,3,4-trione 3-arylhydrazono	193
1-Phenyl-2,3-dimethyl- 4-amino-5-iso- pyrazolone	Pentane-2,3,4-trione 3-arylhydrazono	194
1-Phenyl-3,5-dimethyl- 4-amino-pyrazole	Pentane-2,3,4-trione 3-arylhydrazono	195
3,5-Dimethyl-4- amino-pyrazole	Pentane-2,3,4-trione 3-arylhydrazono	196
5-Amino-3-isopropyl- 1,2,4-triazole	Pentane 2,3,4-trione 3-arylhydrazono	197
4-Nitro	$\text{CH}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	198
4-Nitro	$\text{CH}_3\text{COC}(\text{COCH}_2\text{Cl})=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
4-Nitro	$\text{CH}_3\text{COC}(\text{COCH}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
	$\text{CH}_3\text{COC}(\text{COCH}_2\text{H}_3)=\text{NNHC}_6\text{H}_4$	200
Pentane 2,4-dione enol ethyl ether		
1,5-Dichloropentane-2,4-dione		
Heptam 2,4-dione		
Heptane 2,4-dione		

6-Methylheptane-2,4-dione	4-Nitro	$(\text{CH}_3)_2\text{CHCH}_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
Heptane-2,4-dione	4-Chloro	$\text{C}_6\text{H}_5\text{COC}(\text{COCH}_3)_2=\text{NNHC}_6\text{H}_4\text{Cl-}p$	199
Heptane-2,4,6-trione	—	$(\text{C}_6\text{H}_5)_2\text{NHN}=\text{CHCOC}(\text{H})=\text{NC}_6\text{H}_5\text{CO}$	201
Nonane-1,6-dione	—	2,6-Dimethyl-3,5-diphenylazopynone	202
—	4-Chloro	$n\text{-C}_3\text{H}_7\text{COC}(\text{COCH}_3)_2=\text{NNHC}_6\text{H}_4\text{Cl-}p$	199
—	4-Nitro	$n\text{-C}_3\text{H}_7\text{COC}(\text{COCH}_3)_2=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
4-Phenylbutane-1,3-dione	—	$\text{C}_6\text{H}_5\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_5$ (90)	42, 187
—	—	$\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_5$ (25)	203, 204
—	2-Nitro	$(\text{C}_6\text{H}_5)_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}o$	205
—	4-Nitro	$(\text{C}_6\text{H}_5)_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (quant.)	205, 206
4-Acetamido	—	$\text{C}_6\text{H}_5\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NHCOCH}_3\text{-}p$	207
2,4-Dibromo	—	$(\text{C}_6\text{H}_5)_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_3\text{Br}_2\text{-}2,4$	42
2,4,6-Tribromo	—	$(\text{C}_6\text{H}_5)_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_2\text{Br}_3\text{-}2,4,6$	42
3,5-Dimethyl-4-aminopyrazole	—	1-Phenylbutane-1,2,3-trione 2-(3,5-dimethyl-4-pyrazolyl)hydrazene	196
4-Nitro	—	$o\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	208
4-Nitro	—	2,4-(CH_3O) $_2\text{C}_6\text{H}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	208
—	—	2,4-($\text{C}_2\text{H}_5\text{O}$) $_2\text{C}_6\text{H}_3\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_5$ (good)	210, 209
4-Nitro	—	$\text{C}_6\text{H}_5\text{CH}_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
4-Nitro	—	$[(\text{CH}_3)_2\text{CHCH}_2\text{CO}]_2\text{C}=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
4-Nitro	—	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{COC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (70)	211
—	—	$(\text{C}_6\text{H}_5\text{CO})_2\text{C}=\text{NNHC}_6\text{H}_5$	187
4-Nitro	—	$(\text{C}_6\text{H}_5\text{CO})_2\text{C}=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199
4-Sulfo	—	$(\text{C}_6\text{H}_5\text{CO})_2\text{C}=\text{NNHC}_6\text{H}_4\text{SO}_3\text{H-}p$	187
4-Nitro	—	$(p\text{-O}_2\text{NC}_6\text{H}_4\text{CO})_2\text{C}=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	199

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† This product was obtained by the use of excess diazonium salt.

TABLE I—Continued

C. β -Diketones—Continued		References
Substituent(s) in Aniline*	Product (Yield, %)	
1,3-Diketone		
1-(2,4,6-Trimethoxyphenyl)-3-phenylpropane-1,3-dione	3,5-(CH ₃ O) ₂ C ₆ H ₃ CO(COC(C ₆ H ₅)=NNHC ₆ H ₅)	212
1-(2,4,6-Trimethoxyphenyl)-3-phenylpropane-1,3-dione	2,4,6-(CH ₃ O) ₃ C ₆ H ₂ CO(COC(C ₆ H ₅)=NNHC ₆ H ₅)	209
1-(2,4,6-Trimethoxyphenyl)-3- <i>p</i> -anisylpropane-1,3-dione	2,4,6-(CH ₃ O) ₃ C ₆ H ₂ CO(COC(C ₆ H ₄ OC(CH ₃) ₃)=NNHC ₆ H ₅)	209
1-(2,4,6-Trimethoxyphenyl)-3-(2-ethoxyphenyl)propane-1,3-dione	2,4,6-(CH ₃ O) ₃ C ₆ H ₂ CO(COC(C ₆ H ₄ OC ₂ H ₅ - <i>p</i>)=NNHC ₆ H ₅)	209
1-(2,4,6-Trimethoxyphenyl)-3-(3-methoxy-4-ethoxyphenyl)propane-1,3-dione	2,4,6-(CH ₃ O) ₃ C ₆ H ₂ CO(COC(C ₆ H ₃ OC ₂ H ₅ -3-OC ₂ H ₅ -4)=NNHC ₆ H ₅)	209
1,4-Diphenylbutane-1,3-dione	C ₆ H ₅ CH ₂ COC(COC ₆ H ₅)=NNHC ₆ H ₅ (quant.)	213
1,5-Diphenylpentane-2,4-dione	(C ₆ H ₅ CH ₂ CO) ₂ C=NNHC ₆ H ₄ NO ₂ - <i>p</i>	199
1-(2-Hydroxy-1-naphthyl)-3-phenylpropane-1,2,3-trione	1-(2-Hydroxy-1-naphthyl)-3-phenylpropane-1,2,3-trione 2-phenylhydrazone (79)	214
2-Methyl	CH ₃ COC(COCO ₂ H)=NNHC ₆ H ₅	215
4-Methyl	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₅ (96)	216, 187
3-Chloro	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ CH ₃ - <i>o</i> (78)	216
3-Bromo	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ CH ₃ - <i>p</i> (98)	216
2-Nitro	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ Cl- <i>m</i> (99)	216
3-Nitro	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ Br- <i>m</i> (99)	216
4-Nitro	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ NO ₂ - <i>o</i> (75)	216
	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ NO ₂ - <i>m</i> (90)	216
	CH ₃ COC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ NO ₂ - <i>p</i> (76)	216

Dinitryl Naphthalenebichelidonate	—	Dinitryl β,δ -diphenylazoxanthochelidonate [¶]	202
α,γ -Dioxo- γ -phenylbutyric acid	—	$C_6H_5(COCOCOCOC_2H_5) = NNC_6H_5$	217
Ethyl α,γ -dioxo- γ -phenylbutyrate	—	$C_6H_5(COCOCOCOC_2H_5) = NNC_6H_5$	187, 217
2-Carboxy	—	$C_6H_5(COCOCOCOC_2H_5) = NNC_6H_5(CO_2H-o$	217
Benzidine	—	$\beta,\beta'-(4,4'-Biphenylenedi)hydrazono$ bis(ethyl α,β,γ - trioxo- γ -phenylbutyrate)	217
Ethyl α,γ -dioxo- γ -(<i>p</i> - acetamidophenyl)butyrate	—	Ethyl α,β,γ -trioxo- γ -(<i>p</i> -acetamidophenyl)butyrate	218
Ethyl 2,4-dioxo-6-methyl-5- heptenoate	4-Nitro	Ethyl 2,3,4-trioxo-6-methyl-5-heptenoate	9
Ethyl α,γ -dioxo- γ -(<i>p</i> -3,4- alloacetethoxy-2,5-dimethyl- pyrazol-1-yl)phenylbutyrate	—	3- <i>p</i> -nitrophenylhydrazono Ethyl α,β,γ -trioxo- γ -(<i>p</i> -(3,4-dicarbethoxy-2,5- dimethylpyrazol-1-yl)phenyl)butyrate β -phenylhydrazono	219

D. Cyclic β -Diketones

Cyclohexane-1,3-dione	4-Methyl	Cyclohexane-1,2,3-trione 2- <i>p</i> -tolylhydrazono	43
5,5-Dimethylcyclohexane-1,3- dione (methone)	—	5,5-Dimethylcyclohexane-1,2,3-trione 2-phenylhydrazono	44, 45
	2-Methyl	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>o</i> -tolylhydrazono	45
	3-Methyl	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>m</i> -tolylhydrazono	45
	4-Methyl	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>p</i> -tolylhydrazono	45
4-Nitro	4-Nitro	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>p</i> -nitrophenyl- hydrazono	46

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

¶ Other products were also isolated from the reaction mixture.

TABLE I—Continued
D. Cyclic β -Diketones—Continued

Substituent(s) in Aniline*	Product (Yield, %)	References
2-Arsono	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>o</i> -arsonophenyl- hydrazono	220
3-Arsono	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>m</i> -arsonophenyl- hydrazono	220
4-Arsono	5,5-Dimethylcyclohexane-1,2,3-trione 2- <i>p</i> -arsonophenyl- hydrazono	220
α -Naphthylamine	5,5-Dimethylcyclohexane-1,2,3-trione 2- α -naphthyl- hydrazono	45
β -Naphthylamine	5,5-Dimethylcyclohexane-1,2,3-trione 2- β -naphthyl- hydrazono	45
Benziidine	2,2'-(4,4'-Biphenylene)dihydrazono bis-(5,5-dimethyl- cyclohexane-1,2,3-trione)	46
3,3'-Dimethyl- benzidine	2,2'-(3,3'-Dimethyl-4,4'-biphenylene)dihydrazono bis- [5,5-dimethylcyclohexane-1,2,3-trione]	46
3,3'-Dimethoxy- benzidine	2,2'-(3,3'-Dimethoxy-4,4'-biphenylene)dihydrazono bis- [5,5-dimethylcyclohexane-1,2,3-trione]	46
5-Phenylcyclohexane-1,3-dione	5-Phenylcyclohexane-1,2,3-trione 2-phenylhydrazono (quant.)	221

4-Cyano-6-phenylcyclohexane-1,3-dione	—	4-Cyano-5-phenylcyclohexane-1,2,3-trione 2-phenylhydrazine	43
4-Carbethoxy-5-phenylcyclohexane-1,3-dione	—	4-Carbethoxy-5-phenylcyclohexane-1,2,3-trione 2-phenylhydrazine	43
5-(2-Furyl)cyclohexane-1,3-dione	—	5-(2-Furyl)cyclohexane-1,2,3-trione 2-phenylhydrazine	221
Fillicinic acid	—	6,6-Dimethylcyclohexane-1,2,3,4,5-pentaone 2,4-diphenylhydrazine	222
2-Butyryl-6,6-dimethylcyclohexane-1,3,5-trione	—	2-Butyryl-6,6-dimethylcyclohexane-1,3,4,5-tetraone 4-phenylhydrazine	222
2,2'-Methylenebis-(6,6-dimethylcyclohexane-1,3,5-trione)	—	2,2'-Methylenebis-(6,6-dimethylcyclohexane-1,3,4,5-tetraone 4-phenylhydrazine)	223
Indan-1,3-dione	—	Indan-1,2,3-trione 2-phenylhydrazine (35)	47
4-Methyl	4-Methyl	Indan-1,2,3-trione 2- <i>p</i> -tolylhydrazine	48
4-Nitro	4-Nitro	Indan-1,2,3-trione 2- <i>p</i> -nitrophenylhydrazine	48
β -Naphthylamine	β -Naphthylamine	Indan-1,2,3-trione 2- β -naphthylhydrazine	48
Benzidine	Benzidine	2,2'-(4,4'-Biphenylene)dihydrazono)bis(indan-1,2,3-trione)	48
2,4-Dioxo-1,2,3,4,4 α ,9,10,10 α -octahydrophenanthrene	—	2,3,4-Trioxo-1,2,3,4,4 α ,9,10,10 α -octahydrophenanthrene 3-phenylhydrazine	224

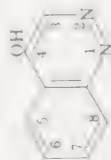
Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE I—Continued
E. 4-Hydroxycinnolines from o-Aminoketones

Substituent(s) in 4-Hydroxycinnoline

(Yield, %)



References

Substituent	References
Acetophenone	
2-Amino	37, 22, 39
2-Amino-1-methyl	164
2-Amino-3-methyl	164
2-Amino-6-methoxy	224a
2-Amino-5-methoxy	224a
2-Amino-4-methoxy	224a
2-Amino-3-methoxy	167a
2-Amino-5-chloro	22, 39
2-Amino-4-chloro	37, 39, 161
2-Amino-3-chloro	22
2-Amino-5-bromo	39, 22
2-Amino-3-bromo	22
2-Amino-5-iodo	39
2-Amino-6-nitro	165
2-Amino-5-nitro	39, 22, 159
2-Amino-4-nitro	165, 166
2-Amino-3-nitro	163, 164
2-Amino-5-cyano	164
2-Amino-4-acetyl	22
2-Amino-3-acetamido	165
2-Amino-phenylazo	39
2-Amino-3-(3-acetylphenylazo)	166
2-Amino-3-(3-acetylphenylazo) (50)	166
— (70–75)	
7-Methyl (58)	37, 22, 39
8-Methyl (78)	164
5-Methoxy (55)	224a
6-Methoxy (53)	224a
7-Methoxy (63)	224a
8-Methoxy (92)	167a
6-Chloro (74)	22, 39
7-Chloro (90–95)	37, 39, 161
8-Chloro (69)	22
6-Bromo (95)	39, 22
8-Bromo (57)	22
6-Iodo	39
5-Nitro (70)	165
6-Nitro (87)	39, 22, 159
7-Nitro (76)	165, 166
8-Nitro (70)	163, 164
8-Chloro** (45)	164
6-Cyano (70–90)	22
7-Acetyl (17)	165
6-Acetamido (33)	39
6-Phenylazo (60)	166
6-(3-Acetylphenylazo) (50)	166

2-Amino-4,5-dimethyl 38
 2-Amino-4,6-dimethoxy 167b
 2-Amino-4,5-dichloro 162
 2-Amino-3,4-dichloro 162
 2-Amino-3,5-dibromo 39
 2-Amino-5-chloro-4-methyl 162, 24
 2-Amino-5-chloro-4-methyl 162
 2-Amino-5-bromo-4-methyl 162
 2-Amino-4-methyl-5-nitro 164
 2-Amino-4-chloro-5-nitro 161
 2-Amino-4-chloro-3-nitro 161

2-Nitro-4-methyl Chloride

2-Amino 24
 2-Amino-5-methyl 38
 2-Amino-5-chloro 24
 2-Amino-4,5-dimethyl 38

Phenacyl Bromide

2-Amino 24
 2-Amino-5-chloro 24
 2-Amino-5-bromo 24

Propiophenone

2-Amino 40, 39
 2-Amino-5-chloro 40
 2-Amino-5-bromo 39, 40
 2-Amino-5-nitro 39, 40
 2-Amino-3-nitro 40

6,7-Dimethyl (91)
 6,7-Dimethoxy (67)
 6,7-Dichloro (91)
 7,8-Dichloro (59)
 6,8-Dibromo (65)
 6-Chloro-7-methyl (90)
 8-Chloro-7-methyl (75)
 6-Bromo-7-methyl (37)
 7-Methyl-6-nitro (76)
 7-Chloro-6-nitro (57)
 7-Chloro-8-nitro (57)

3-Chloro (85)
 3-Chloro-6-methyl (87)
 3,6-Dichloro (73)
 3-Chloro-6,7-dimethyl (80)

3-Bromo (73)
 3-Bromo-6-chloro (77)
 3,6-Dibromo (76)

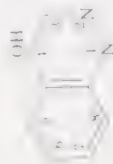
3-Methyl (83)
 6-Chloro-3-methyl (94)
 6-Bromo-3-methyl (76)
 3-Methyl-6-nitro (65)
 3-Methyl-8-nitro (96)

Note: References 177-480 are on pp. 136-142.

** The 8-chloro compound is obtained if the diazotization is run in hydrochloric acid.

TABLE I—Continued
E. 4-Hydrozycinnolines from o-Aminoketones—Continued

Substituent in 4-Hydrozycinnoline
 (Yield, %)



Reactant

Miscellaneous o-Aminoketones

- 2-Aminobutyrophenone
 γ -(2-Aminobenzoyl)butyric acid
 β -(2-Amino-4,5-dimethoxybenzoyl)propionic acid
 Ethyl β -(2-amino-4-carbethoxybenzoyl)propionate
 3,4-Diacetyl-4,4'-diaminobenzobenzene
 5-Amino-6-acetylinthane
 4-Amino-5-acetylinthane
 5-Amino-6-chloroacetylinthane
 1,2,3,4-Tetrahydro-6-amino-7-acetylnaphthalene
 1,2,3,4-Tetrahydro-5-amino-6-acetylnaphthalene
 1,2,3,4-Tetrahydro-6-amino-7-chloroacetylnaphthalene

Note: References 177-480 are on pp. 136-142.

References

- 3-Ethyl (68) 41
 3-Carboxyethyl (53) 41
 3-Carboxymethyl-6,7-dimethoxy (71) 22
 3-Carboxymethyl-7-carbethoxy (13) 160
 4,4'-Dihydroxy-6,6'-azocinnoline (69) 166
 6,7-Cyclopenteno (60) 38
 7,8-Cyclopenteno 38
 3-Chloro-6,7-cyclopenteno (57) 38
 6,7-Cyclohexeno (70) 38
 7,8-Cyclohexeno 38
 3-Chloro-6,7-cyclohexeno (67) 38

TABLE II

COUPLING OF DIAZONIUM SALTS WITH β -KETO ACIDS, ESTERS, AND AMIDES

1. β -Keto Acids		References
Substituent(s) in Aniline*	Product (Yield, %)	
—	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_5$ (73-82)	55, 53, 54, 225
Acetoacetic acid	$\text{CH}_3\text{COC}(\text{N}=\text{NC}_6\text{H}_5)=\text{NNHC}_6\text{H}_5^\dagger$ (41)	52, 226
4-Methyl	$\text{C}_6\text{H}_5\text{C}(\text{CH}_3)\text{N}=\text{NC}_6\text{H}_5=\text{NNHC}_6\text{H}_5^\ddagger$	140
2-Methoxy	$(\text{CH}_3\text{COCH}=\text{NC}_6\text{H}_5)(\text{CH}_3-p)=\text{NNHC}_6\text{H}_4\text{CH}_3-p^\ddagger$	52
2-Nitro	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_4\text{OCH}_3-o$	227
3-Nitro	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_4\text{NO}_2-o$	228, 229
4-Nitro	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_4\text{NO}_2-m$	228
2,4-Dibromo	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_4\text{NO}_2-p$	228
2-Bromo-4-nitro	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_3\text{Br}_2-2,4$	152
2,4,6-Trichloro	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_3\text{Br}-2-\text{NO}_2-4$	228
2,4,6-Tribromo	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_2\text{Cl}_3-2,4,6$	230
2,6-Dibromo-4-nitro	$\text{CH}_3\text{COCH}=\text{NNHC}_6\text{H}_2\text{Br}_2-2,6-\text{NO}_2-4$	230
α -Naphthylamine	$\text{CH}_3\text{COCH}=\text{NNHC}_{10}\text{H}_7-\alpha$	228
Propionylacetic acid	$\text{CH}_3\text{COC}(\text{N}=\text{NC}_{10}\text{H}_7-\alpha)=\text{NNHC}_{10}\text{H}_7-\alpha^\ddagger$	225
α -Acetopropionic acid	$\text{C}_6\text{H}_5\text{C}(\text{OCH}_3)\text{N}=\text{NC}_6\text{H}_5=\text{NNHC}_6\text{H}_4\text{NO}_2-p$	52
Tetronic acid	$\text{C}_6\text{H}_5\text{C}(\text{CN}=\text{NC}_6\text{H}_5)=\text{NNHC}_6\text{H}_5^\ddagger$	130a
Benzoylethacetic acid	γ -Hydroxy- α,β -dioxobutyric acid lactone β -phenylhydrazine	153
	$\text{C}_6\text{H}_5\text{C}(\text{OCH}_3)\text{N}=\text{NNHC}_6\text{H}_5$	231
	$\text{C}_6\text{H}_5\text{COC}(\text{N}=\text{NC}_6\text{H}_5)=\text{NNHC}_6\text{H}_5^\ddagger$ (39)	232
		204, 203

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† This product was obtained when 2 equivalents of the diazonium salt were used.

‡ This product was obtained when 3 equivalents of the diazonium salt were used.

TABLE II—Continued

A. β -Keto Acids—Continued		Product (Yield, %)	References
β -Keto Acid	Substituent(s) in Aniline*		
	4-Methoxy	$C_6H_5COCH=NNHC_6H_4OCH_3$ - <i>p</i>	130a
	4-Chloro	$C_6H_5COCH=NNHC_6H_4Cl$ - <i>p</i>	130a
	2-Nitro	$C_6H_5COCH=NNHC_6H_4NO_2$ - <i>o</i>	232
	3-Nitro	$C_6H_5COCH=NNHC_6H_4NO_2$ - <i>m</i>	232
	4-Nitro	$C_6H_5COCH=NNHC_6H_4NO_2$ - <i>p</i>	232, 130a
	4-Carboxy	$C_6H_5COCH=NNHC_6H_4CO_2H$ - <i>p</i>	130a
	2-Hydroxy-5-chloro	o -HO $_2C$ $_6$ H $_4$ CO(N $_2$ C $_6$ H $_3$ OH-2-(1-5)=NNHC $_6$ H $_3$ OH-2-Cl-5	232a
	—	CO(CH=NNHC $_6$ H $_5$) $_2$ (39)	56
	4-Methyl	CO(CH=NNHC $_6$ H $_4$ CH $_3$ - <i>p</i>) $_2$ (80)	57
2-Oxo-1-propanesulfonic acid	4-Chloro	CO(CH=NNHC $_6$ H $_4$ Cl- <i>p</i>) $_2$ (70)	57
	—	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_5$	58
	4-Chloro	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ Cl- <i>p</i>	58
	4-Bromo	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ Br- <i>p</i>	58
	2-Nitro	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ NO $_2$ - <i>o</i>	58
	3-Nitro	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ NO $_2$ - <i>m</i>	58
	4-Nitro	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ NO $_2$ - <i>p</i>	58
	2,4-Dichloro	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_3$ Cl $_2$ -2,4	58
	2,4-Dibromo	CH $_3$ COC(SO $_3$ H)=NNHC $_6$ H $_3$ Br $_2$ -2,4	58
	—	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_5$ (60)	59
2-Oxo-2-phenyl-1-ethanesulfonic acid	4-Chloro	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ Cl- <i>p</i>	59
	4-Bromo	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ Br- <i>p</i>	59
	2-Nitro	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ NO $_2$ - <i>o</i>	59
	4-Nitro	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_4$ NO $_2$ - <i>p</i>	59
	2,4-Dichloro	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_3$ Cl $_2$ -2,4	59
	2,4-Dibromo	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_3$ Br $_2$ -2,4	59
	2,4,6-Trichloro	C $_6$ H $_5$ COC(SO $_3$ H)=NNHC $_6$ H $_2$ Cl $_3$ -2,4,6	59
	—		
	—		
	—		

2,4,6-Tribromo	$C_6H_3COC(SO_3H)=NNHC_6H_2Br_3$ 2,4,6	59
4-Bromo-2-nitro	$C_6H_4COC(SO_3H)=NNHC_6H_3Br$ 4- NO_2 2	59
<i>B. β-Keto Esters</i>		
Substituent(s) in Aniline*	Product (Yield, %)	References
—	$HCOC(CO_2C_2H_5)=NNHC_6H_5$	233
—	$CH_3COC(CO_2C_2H_5)=NNHC_6H_5$ (94-98)	236, 6, 7, 234, 235
2-Methyl	$C_6H_5N=NC(CO_2C_2H_5)=NNHC_6H_5$ † (80)	60, 140
4-Methyl	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4CH_3$ -o (80-90)	237, 238
—	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4CH_3$ -p (95)	238, 7, 234, 237
2-Chloro	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4Cl$ -o	239
3-Chloro	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4Cl$ -m (78)	74a, 239
4-Chloro	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4Cl$ -p	239
4-Chloro	$p\text{-}ClC_6H_4N=NC(CO_2C_2H_5)=NNHC_6H_4Cl$ -p†	239a
2-Bromo	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4Br$ -o	239
2-Nitro	$(CH_3COC(CO_2C_2H_5)=NNHC_6H_4NO_2$ -o	228, 229, 239
3-Nitro	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4NO_2$ -m	228
—	$m\text{-}O_2NC_6H_4N=NC(CO_2C_2H_5)=NNHC_6H_4NO_2$ -m†	240
4-Nitro	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4NO_2$ -p (quant.)	241, 228, 239
4-Ethoxy	$p\text{-}C_2H_5OC_6H_4N=NC(CO_2C_2H_5)=NNHC_6H_4OC_2H_5$ -p (57)†	240
2-Carboxy	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4CO_2H$ -o (90)	237
3-Carboxy	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4CO_2H$ -m	242
4-Acetamido	$CH_3COC(CO_2C_2H_5)=NNHC_6H_4NHCOCH_3$ -p	243

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† This product was obtained when 2 equivalents of the diazonium salt were used.



TABLE II—Continued

B. β -Keto Esters—Continued		References
Substituent(s) in Aniline*	Product (Yield, %)	
4-Sulfanyl	$(\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5))=\text{NNHC}_6\text{H}_4\text{SO}_2\text{NH}_2\text{-}p$	244
2,4-Dimethyl	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3(\text{CH}_3)_2\text{-}2,4$ (75)	237
2,4-Dichloro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Cl}_2\text{-}2,4$ (85)	235
3,5-Dichloro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3(\text{Cl}_2)_3\text{-}3,5$	245
3,5-Dibromo	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Br}_2\text{-}3,5$	245
2,4,6-Trichloro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Cl}_3\text{-}2,4,6$ (quant.)	230, 246
2,4,6-Tribromo	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Br}_3\text{-}2,4,6$ (quant.)	230, 239
3,4,5-Trichloro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Br}_3\text{-}3,4,5$	245
2-Methyl-4-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3\text{-}2\text{-NO}_2\text{-}4$	247
2-Methyl-5-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3\text{-}2\text{-NO}_2\text{-}5$	247
2-Methyl-6-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3\text{-}2\text{-NO}_2\text{-}6$	247
4-Methyl-2-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3\text{-}4\text{-NO}_2\text{-}2$ (90)	247, 229
4-Methyl-3-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3\text{-}4\text{-NO}_2\text{-}3$	247
2-Chloro-4-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Cl-}2\text{-NO}_2\text{-}4$	248
4-Chloro-2-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Cl-}4\text{-NO}_2\text{-}2$	228
2-Bromo-4-nitro	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Br-}2\text{-NO}_2\text{-}4$	245
3,5-Dichloro-4-bromo	Ethyl α,β -dioxobutyrate α -(3,5-dichloro-4-bromophenyl-hydrazone)	248
2,6-Dichloro-4-nitro	Ethyl α,β -dioxobutyrate α -(2,6-dichloro-4-nitrophenyl-hydrazone)	228
2,6-Dibromo-4-nitro	Ethyl α,β -dioxobutyrate α -(2,6-dibromo-4-nitrophenyl-hydrazone)	228
2-Bromo-4-methyl-5-nitro	Ethyl α,β -dioxobutyrate α -(2-bromo-4-methyl-5-nitrophenyl-hydrazone)	247
2-Bromo-4-methyl-6-nitro	Ethyl α,β -dioxobutyrate α -(2-bromo-4-methyl-6-nitrophenyl-hydrazone)	247

2-Bromo-6-methyl-4-nitro	Ethyl α,β -dioxobutyrate α -(2-bromo-6-methyl-4-nitrophenylhydrazine)	247
4-Bromo-2-methyl-6-nitro	Ethyl α,β -dioxobutyrate α -(4-bromo-2-methyl-6-nitrophenylhydrazine)	247
2,6-Dibromo-3-nitro-4-methyl	Ethyl α,β -dioxobutyrate α -(2,6-dibromo-3-nitro-4-methylphenylhydrazine)	247
4,6-Dibromo-2-methyl-5-nitro	Ethyl α,β -dioxobutyrate α -(4,6-dibromo-2-methyl-5-nitrophenylhydrazine)	247
α -Naphthylamine	Ethyl α,β -dioxobutyrate α -(α -naphthylhydrazine) (quant.)	249, 237
β -Naphthylamine	Ethyl α,β -dioxobutyrate α -(β -naphthylhydrazine)	237, 249
2-Aminoanthraquinone	Ethyl α,β -dioxobutyrate α -(2-anthraquinonylhydrazine) (quant.)	250
3-Aminocarbazole	Ethyl α,β -dioxobutyrate α -(3-carbazolyldiazine)	251
N-Ethyl-3-aminocarbazole	Ethyl α,β -dioxobutyrate α -(N-ethyl-3-carbazolyldiazine)	251
<i>p</i> -(3-Carboxy-4-hydroxyphenylazo)	Ethyl α,β -dioxobutyrate α -arylhydrazine	252
<i>p</i> -(<i>p</i> -Dimethylsulfamylphenylsulfamyl)	Ethyl α,β -dioxobutyrate α -[<i>p</i> -(<i>p</i> -dimethylsulfamyl)phenylsulfamyl]	244
3,5-Dimethyl-4-aminopyrazole	Ethyl α,β -dioxobutyrate α -(3,5-dimethyl-4-pyrazolyldiazine)	196
1-Phenyl-3,5-dimethyl-4-aminopyrazole	Ethyl α,β -dioxobutyrate α -(1-phenyl-3,5-dimethyl-4-pyrazolyldiazine)	195
<i>p</i> -(3,4-Dicarbo-methoxy-5-methyl-1-pyrazolyl)	Ethyl α,β -dioxobutyrate α -arylhydrazine	253

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE II—Continued

<i>B. β-Keto Esters—Continued</i>		References
β -Keto Ester	Product (Yield, %)	
Ethyl acetoacetate (<i>ConL</i>)	Ethyl α,β -dioxobutylate α -(5-isopropyl-1,2,4-triazol-3-yl)-hydrazine	197
<i>l</i> -Menthyl acetoacetate	α,α' -(4,4'-Biphenylenedihydrazono)bis(ethyl α,β -dioxobutylate) (98)	254, 255
Methyl <i>p</i> -chloroacetoacetate	α,β -dioxobutylate	256
Ethyl <i>p</i> -chloroacetoacetate	α,β -dioxobutylate	146
	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_{10}\text{H}_{19})=\text{NNHC}_6\text{H}_5$	146
	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_{10}\text{H}_{19})=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i>	146
	<i>p</i> - $\text{CH}_3\text{C}_6\text{H}_4\text{N}-\text{N}(\text{C}(\text{CO}_2\text{C}_{10}\text{H}_{19}))=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i> †	146
	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_{10}\text{H}_{19})=\text{NNHC}_6\text{H}_4\text{Cl}$ - <i>p</i>	146
	$\text{CH}_3\text{COC}(\text{CO}_2\text{C}_{10}\text{H}_{19})=\text{NNHC}_6\text{H}_4\text{Br}$ - <i>p</i>	146
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	257
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i>	257
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i>	257
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$	152, 257
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i>	257
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i>	257
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Cl}$ - <i>p</i>	152
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i>	248
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Cl}_2$ -2,4	152
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Cl}_3$ -2,4,6	230
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Br}_3$ -2,4,6	230
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Cl}_2\text{-NO}_2$ -4	248
	$\text{ClCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Cl}_2$ -2,6- NO_2 -4	248

Methyl γ -bromoacetate	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	258
—	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$	258
—	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$	258
Ethyl γ -bromoacetate	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$ (good)	259, 230,
—	—	258
—	—	258
—	—	258
—	—	152
—	—	228
—	—	228
—	—	228
—	—	152
—	—	230
—	—	230
—	—	228
—	—	228
—	—	260
—	—	260
—	—	260
—	—	261, 262
—	—	261, 262
—	—	265, 140,
—	—	263, 264
—	—	264
—	—	263, 266
—	—	266
—	—	264
—	—	267
—	—	263
2-Methyl	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$	258
4-Methyl	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$	258
4-Bromo	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Br}$	152
2-Nitro	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	228
3-Nitro	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	228
4-Nitro	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	228
2,4-Dibromo	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Br}_2$	152
2,4,6-Trichloro	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Cl}_3$	230
2,4,6-Tribromo	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Br}_3$	230
2-Bromo-4-nitro	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Br}_2$	228
2,6-Dibromo-4-nitro	$\text{BrCH}_2\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_2\text{Br}_2$	228
—	$n\text{-C}_3\text{H}_7\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$	260
4-Nitro	$n\text{-C}_3\text{H}_7\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	260
—	$n\text{-C}_6\text{H}_{13}\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$	260
—	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	261, 262
4-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2$	261, 262
—	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$ (70)	265, 140,
—	—	263, 264
4-Methyl	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$	264
2-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	263, 266
3-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	266
4-Nitro	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$	264
4-Acetamido	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NHCOCH}_3$	267
4-Methyl-2-nitro	$\text{C}_6\text{H}_5\text{COC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3$	263

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

* This product was obtained when 2 equivalents of the diazonium salt were used.

TABLE II—Continued

B. β -Keto Esters—Continued			References
β -Keto Ester	Substituent (s) in Aniline*	Product (Yield, %)	
Methyl <i>o</i> -methoxybenzoyl- acetate	—	$o\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	268
Methyl <i>m</i> -methoxybenzoyl- acetate	4-Nitro	$o\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	268
	—	$m\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	268
Methyl <i>p</i> -methoxybenzoyl- acetate	4-Nitro	$m\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	268
	—	$p\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	268
Methyl <i>o</i> -chlorobenzoyl- acetate	4-Nitro	$p\text{-CH}_3\text{OC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	268
	—	$o\text{-ClC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	269
Methyl <i>m</i> -chlorobenzoyl- acetate	4-Nitro	$o\text{-ClC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	269
	—	$m\text{-ClC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	269
Methyl <i>p</i> -chlorobenzoyl- acetate	4-Nitro	$m\text{-ClC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	269
	—	$p\text{-ClC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	269
Dimethyl oxalacetate	4-Nitro	$p\text{-ClC}_6\text{H}_4\text{COC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	269
	—	$\text{CH}_3\text{O}_2\text{CCOC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$ (40)	62
Diethyl oxalacetate	Benzidine	$[\text{CH}_3\text{O}_2\text{CCOC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{-}]_2$ (65)	270
	—	$\text{C}_2\text{H}_5\text{O}_2\text{CCOC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$ (75)	62, 61
	—	$\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$ † (76)	63, 61
	2-Methyl	$\text{C}_2\text{H}_5\text{O}_2\text{CCOC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ (76)	62, 271
	4-Bromo	$o\text{-CH}_3\text{C}_6\text{H}_4\text{N}=\text{NC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ (81)	63
	—	$\text{C}_2\text{H}_5\text{O}_2\text{CCOC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Br}$ (82)	66
	—	$p\text{-BrC}_6\text{H}_4\text{N}=\text{NC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Br}$ † (41)	66
	2,4-Dibromo	$\text{C}_2\text{H}_5\text{O}_2\text{CCOC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Br}_2$ 2,4	272

Benzidine	4,4'-Biphenylenedihydrazonobis(diethyl dioxosuccinate) (76)	270, 273
3,3'-Dimethylbenzidine	3,3'-Dimethyl-4,4'-biphenylenedihydrazonobis(diethyl dioxosuccinate) (60)	273, 270
3,3'-Dimethoxybenzidine	3,3'-Dimethoxy-4,4'-biphenylenedihydrazonobis(diethyl dioxosuccinate) (55-60)	273, 270
Diethyl acetonedicarboxylate	$C_2H_5O_2CCH_2COC(CO_2C_2H_5)=NNHC_6H_5$ (86)	65, 274
2-Methyl	$C_2H_5O_2CCH_2COC(CO_2C_2H_5)=NNHC_6H_4CH_3-o$ (94)	65
4-Methyl	$C_2H_5O_2CCH_2COC(CO_2C_2H_5)=NNHC_6H_4CH_3-p$ (90)	65
4-Nitro	$C_2H_5O_2CCH_2COC(CO_2C_2H_5)=NNHC_6H_4NO_2-p$	64
2-Carboxy	$C_2H_5O_2CCH_2COC(CO_2C_2H_5)=NNHC_6H_4CO_2H-o$ (70)	65
2,4-Dimethyl	$C_2H_5O_2CCH_2COC(CO_2C_2H_5)=NNHC_6H_3(CH_3)_2-2,4$	65
4-(<i>p</i> -Phenylmercaptobenzoyl)	Diethyl α,β -dioxoglutarate α -(<i>p</i> -phenylmercaptobenzoyl)-phenylhydrazine] (27)	13
4-(3,4-Dicarbethoxy-5-methyl-1-pyrazolyl)	Diethyl α,β -dioxoglutarate α -[<i>p</i> -(3,4-dicarbethoxy-5-methyl-1-pyrazolyl)phenylhydrazine]	253
Diethyl α,α -diethyl- β -oxoglutarate	Diethyl α,α -diethyl- β - γ -dioxoglutarate γ -phenylhydrazine	274
5-Hydroxy-3-oxo-4-hexenoic acid lactone	5-Hydroxy-3-oxo-2-phenylhydrazono-4-hexenoic acid lactone (60)	275
Diethyl 5-oxo-2-hexendioate	$C_6H_5N=NC(CH=CHCO_2C_2H_5)=NNHC_6H_5\S$ (18)	66
4-Bromo	$C_2H_5O_2CCOC(CH=CHCO_2C_2H_5)=NNHC_6H_4Br-p$ (65)	66
	p -BrC ₆ H ₄ N=NC(CH=CHCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ Br- <i>p</i> §	66
	p -BrC ₆ H ₄ N=NC(CO ₂ C ₂ H ₅)=CHC(COCO ₂ C ₂ H ₅)=NNHC ₆ H ₄ Br- <i>p</i>	66
4-Ethoxy	$C_2H_5O_2CCOC(CH=CHCO_2C_2H_5)=NNHC_6H_4OC_2H_5-p$ (36-43)	66

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† This product was obtained when 2 equivalents of diazonium salt were used.

§ This product was obtained by coupling in the presence of ammonia.

|| This product was obtained by coupling in alcoholic hydrochloric acid.

¶ This product was obtained by coupling in the presence of sodium carbonate.

TABLE II—Continued

<i>B. β-Keto Esters—Continued</i>		
α -Keto Ester	Substituent(s) in Aniline*	Product (Yield, %)
Oxalldihydrazonobis(ethyl acetate)	—	β, β' -Oxalldihydrazonobis(ethyl α, β -dioxobutyrate) α, α' -diphenylhydrazone**
Malondihydrazonobis(ethyl acetoacetate)	—	β, β' -Mesoxalldihydrazonobis(ethyl α, β -dioxobutyrate) $\alpha, \alpha', \alpha''$ -triphenylhydrazone (72)
	4-Methyl	β, β' -Mesoxalldihydrazonobis(ethyl α, β -dioxobutyrate) $\alpha, \alpha', \alpha''$ -tri- <i>p</i> -tolylhydrazone (50)
References		
		278
		280, 279
		280
<i>C. β-Keto Amides</i>		
β -Keto Amide	Substituent(s) in Aniline*	Product (Yield, %)
Acetoacetanilide	—	$\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_5$ $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>o</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>p</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5$ - <i>p</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Cl}$ - <i>m</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Cl}$ - <i>p</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Br}$ - <i>p</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>o</i> $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_3\text{CH}_3$ -4- NO_2 -2 $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_3\text{Cl}$ -4- NO_2 -2 $\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}(\text{CH}_3)_2$ -2,4,6- NO_2 -3 nitro
	2-Methyl	
	4-Methyl	
	2-Methoxy	
	4-Methoxy	
	4-Ethoxy	
	3-Chloro	
	4-Chloro	
	4-Bromo	
	2-Nitro	
	4-Methyl-2-nitro	
	4-Chloro-2-nitro	
	2,4,6-Trimethyl-3-nitro	
	α -Naphthylamine	
		References
		281, 282
		283
		283
		283
		283
		283
		283
		283
		283
		283
		67, 68
		67, 69
		67, 68
		284
		283

<i>o</i> -Naphthylamine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	283
Anhydrous <i>o</i> -aminobenzaldehyde	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5\text{CHO}$	285
4-(3,4-Dicarbethoxy-2,5-dimethylpyrrolyl)	α,β -Dioxobutylanilide α -arylhydrazine	286
4-(3,4-Dicarbethoxy-5-methyl-1-pyrazolyl)	α,β -Dioxobutylanilide α -arylhydrazine	253
Benzidine	α,α' -(4,4'-Biphenylenedihydrazono)bis-(α,β -dioxobutylanilide)	287
—	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	282
Benzidine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	287
—	$\text{CH}_3\text{COC}(\text{COHNC}_6\text{H}_5)_2 = \text{NNHC}_6\text{H}_5$	282
Benzidine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	287
—	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	282
Benzidine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	287
—	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	282
Benzidine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	287
—	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	282
<i>p</i> -(3,4-Dicarbethoxy-2,5-dimethylpyrrolyl)	<i>p</i> -Ethoxy- α,β -dioxobutylanilide α -arylhydrazine	286
Benzidine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	287
4-Chloro-2-nitro	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	67, 68
—	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	282
Benzidine	$(\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_5)_2)_2 = \text{NNHC}_6\text{H}_5$	287

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

** Some monophenylhydrazones were isolated.

TABLE II—Continued
C. β -Keto Amides—Continued

Keto Amide	Substituent(s) in Aniline*	Product (Yield, %)	References
<i>p</i> -Chloroacetacetanilide	—	$\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{Cl-}p)=\text{NNHC}_6\text{H}_5$	282
<i>p</i> -Bromoacetacetanilide	Benzidine	$[\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{Cl-}p)=\text{NNHC}_6\text{H}_4-]_2$	287
	—	$\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{Br-}p)=\text{NNHC}_6\text{H}_5$	282
<i>p</i> -Sulfamylacetacetanilide	Benzidine	$[\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{Br-}p)=\text{NNHC}_6\text{H}_4-]_2$	287
	2-Nitro	$\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{SO}_2\text{NH}_2-p)=\text{NNHC}_6\text{H}_4\text{NO}_2-o$	288
	3-Nitro	$\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{SO}_2\text{NH}_2-p)=\text{NNHC}_6\text{H}_4\text{NO}_2-m$	288
	4-Nitro	$\text{CH}_3\text{COC}(\text{CONHC}_6\text{H}_4\text{SO}_2\text{NH}_2-p)=\text{NNHC}_6\text{H}_4\text{NO}_2-p$	288
<i>N</i> -(β -Naphthyl)acetacetanilide	—	$\text{CH}_3\text{COC}(\text{CONHC}_{10}\text{H}_7-\alpha)=\text{NNHC}_6\text{H}_5$	282
<i>N</i> -(β -Naphthyl)acetacetanilide	Benzidine	$[\text{CH}_3\text{COC}(\text{CONHC}_{10}\text{H}_7-\alpha)=\text{NNHC}_6\text{H}_4-]_2$	285
	—	$\text{CH}_3\text{COC}(\text{CONHC}_{10}\text{H}_7-\beta)=\text{NNHC}_6\text{H}_5$	282
<i>N,N</i> -Diphenylacetacetamide	Benzidine	$[\text{CH}_3\text{COC}(\text{CONHC}_{10}\text{H}_7-\beta)=\text{NNHC}_6\text{H}_4-]_2$	285
	2-Nitro	$(\text{C}_6\text{H}_5)_2\text{NCOC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2-o$ (80–90)	288
	3-Nitro	$(\text{C}_6\text{H}_5)_2\text{NCOC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2-m$ (80–90)	288
	4-Nitro	$(\text{C}_6\text{H}_5)_2\text{NCOC}(\text{COCH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2-p$ (80–90)	288
<i>N</i> -Sulfamoylacetacetamide	4-Nitro	$\text{CH}_3\text{COC}(\text{CONHSO}_2\text{H})=\text{NNHC}_6\text{H}_4\text{NO}_2-p$	289
<i>N</i> -Sulfamylacetacetamide	4-Nitro	$\text{CH}_3\text{COC}(\text{CONHSO}_2\text{NH}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2-p$	289
Acetoacetanilide, phenylhydrazone	—	$\text{CH}_3\text{C}(\text{—NNHC}_6\text{H}_5)(\text{—NNHC}_6\text{H}_5)\text{CONHC}_6\text{H}_5$	281
<i>Benzoyl</i> acetacetanilide	4-Methyl	$\text{C}_6\text{H}_5\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_5$	282
	4-Methoxy	$\text{C}_6\text{H}_5\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3-p$	283
	4-Ethoxy	$\text{C}_6\text{H}_5\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5-p$	283
	4-Chloro	$\text{C}_6\text{H}_5\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5-p$	283
	Benzidine	$\text{C}_6\text{H}_5\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Cl-}p$	283
	—	$[\text{C}_6\text{H}_5\text{COC}(\text{CONHC}_6\text{H}_5)=\text{NNHC}_6\text{H}_4-]_2$	287

p-Benzoylacetofoluide	$C_6H_5COC(COCONHC_6H_4(CH_3)_p) - NNHC_6H_5$	282
p-Benzoylacetanilide	$[C_6H_5COC(COCONHC_6H_4(CH_3)_p) - NNHC_6H_5]_2$	287
p-Benzoylacetanilide	$C_6H_5COC(COCONHC_6H_4OC(CH_3)_p) - NNHC_6H_5$	282
N-p-Chlorophenylbenzoyl-acetanilide	$[C_6H_5COC(COCONHC_6H_4OC(CH_3)_p) - NNHC_6H_5]_2$	287
	$C_6H_5COC(COCONHC_6H_4OC_2H_5)_p - NNHC_6H_5$	282
	$[C_6H_5COC(COCONHC_6H_4(CH_3)_p) - NNHC_6H_5]_2$	287

Substituents in Product,



Substituent (s) in Aniline	R	R'	References
—	Phenyl	Phenyl	282
2-Methyl	Phenyl	<i>o</i> -Tolyl	283
4-Methyl	Phenyl	<i>p</i> -Tolyl	283
2-Methoxy	Phenyl	<i>o</i> -Anisyl	283
4-Methoxy	Phenyl	<i>p</i> -Anisyl	283
4-Ethoxy	Phenyl	<i>p</i> -Ethoxyphenyl	283
3-Chloro	Phenyl	<i>m</i> -Chlorophenyl	283
4-Chloro	Phenyl	<i>p</i> -Chlorophenyl	283
4-Bromo	Phenyl	<i>p</i> -Bromophenyl	283
α -Naphthylamine	Phenyl	α -Naphthyl	283
β -Naphthylamine	Phenyl	β -Naphthyl	283
Benzidine	Phenyl	Biphenylene	287

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE II—Continued

C. β -Keto Amides—Continued

Substituents in Product,



Substituent R in Reactant, Substituent R in	Substituent(s) in Aniline	R	R'	References
$\text{COCH}_2\text{CONHR}$	—	<i>o</i> -Tolyl	Phenyl	282
<i>o</i> -Tolyl	Benzidine	<i>o</i> -Tolyl	Biphenylene	287
<i>p</i> -Tolyl	—	<i>p</i> -Tolyl	Phenyl	282
—	Benzidine	<i>p</i> -Tolyl	Biphenylene	287
<i>o</i> -Anisyl	—	<i>o</i> -Anisyl	Phenyl	282
—	Benzidine	<i>o</i> -Anisyl	Biphenylene	287
<i>p</i> -Anisyl	—	<i>p</i> -Anisyl	Phenyl	282
—	Benzidine	<i>p</i> -Anisyl	Biphenylene	287
<i>p</i> -Ethoxyphenyl	—	<i>p</i> -Ethoxyphenyl	Phenyl	282
—	Benzidine	<i>p</i> -Ethoxyphenyl	Biphenylene	287
<i>m</i> -Chlorophenyl	—	<i>m</i> -Chlorophenyl	Phenyl	282
—	Benzidine	<i>m</i> -Chlorophenyl	Biphenylene	287
<i>p</i> -Chlorophenyl	—	<i>p</i> -Chlorophenyl	Phenyl	282
—	Benzidine	<i>p</i> -Chlorophenyl	Biphenylene	287
<i>p</i> -Bromophenyl	—	<i>p</i> -Bromophenyl	Phenyl	282
—	Benzidine	<i>p</i> -Bromophenyl	Biphenylene	287
α -Naphthyl	—	α -Naphthyl	Phenyl	282
—	Benzidine	α -Naphthyl	Biphenylene	287
β -Naphthyl	—	β -Naphthyl	Phenyl	282
—	Benzidine	β -Naphthyl	Biphenylene	287

Substituents in Product,



Reactant, Substituent R in	R	R'	
	Phenyl	Phenyl	290
Phenyl	Phenyl	<i>o</i> -Tolyl	290
—	Phenyl	<i>p</i> -Tolyl	290
2-Methyl	Phenyl	<i>o</i> -Anisyl	290
4-Methyl	Phenyl	<i>p</i> -Anisyl	290
2-Methoxy	Phenyl	<i>p</i> -Ethoxyphenyl	290
4-Methoxy	Phenyl	<i>m</i> -Chlorophenyl	290
4-Ethoxy	Phenyl	<i>p</i> -Chlorophenyl	290
3-Chloro	Phenyl	<i>p</i> -Bromophenyl	290
4-Chloro	Phenyl	α -Naphthyl	290
4-Bromo	Phenyl	β -Naphthyl	290
α -Naphthylamine	<i>o</i> -Tolyl	Phenyl	290
β -Naphthylamine	<i>p</i> -Tolyl	Phenyl	290
—	<i>o</i> -Anisyl	Phenyl	290
—	<i>p</i> -Anisyl	Phenyl	290
—	<i>p</i> -Ethoxyphenyl	Phenyl	290
—	<i>m</i> -Chlorophenyl	Phenyl	290
—	<i>p</i> -Chlorophenyl	Phenyl	290
—	<i>p</i> -Bromophenyl	Phenyl	290
—	α -Naphthyl	Phenyl	290
—	β -Naphthyl	Phenyl	290

Note: References 177-480 are on pp. 136-142.

TABLE III

COUPLING OF DIAZONIUM SALTS WITH MALONIC ACIDS, ESTERS, AND AMIDES

A. *Malonic Acids*

Malonic Acid	Substituent(s) in Aniline*	Product (Yield, %)	References
Malonic acid	—	$\text{C}_6\text{H}_5\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_5$ (46)	70
		$\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{C}_6\text{H}_5)=\text{NNHC}_6\text{H}_5^\dagger$	70
	2-Methoxy	$o\text{-CH}_3\text{OC}_6\text{H}_4\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_4\text{OCH}_3\text{-}o$ (67)	290a
	4-Methoxy	$p\text{-CH}_3\text{OC}_6\text{H}_4\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_4\text{OCH}_3\text{-}p$	240
	2-Bromo	$o\text{-BrC}_6\text{H}_4\text{NHN}=\text{CHCO}_2\text{H}$ (30–40)	71
	4-Bromo	$p\text{-BrC}_6\text{H}_4\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_4\text{Br-}p$	71, 170a
	2-Iodo	$o\text{-IC}_6\text{H}_4\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_4\text{I-}o^\ddagger$	71
	2-Nitro	$o\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{CHCO}_2\text{H}$ (50)§	71, 291
	3-Nitro	$m\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}m$	240
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NCH}=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	71, 240
Malonic acid and sodium malate	—	$\text{C}_6\text{H}_5\text{N}=\text{NCH}=\text{NOH}$	71
	2-Methoxy	$o\text{-CH}_3\text{OC}_6\text{H}_4\text{N}=\text{NCH}=\text{NOH}$	71
	2-Chloro	$o\text{-ClC}_6\text{H}_4\text{N}=\text{NCH}=\text{NOH}$	71
	2,4-Dimethyl	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3\text{N}=\text{NCH}=\text{NOH}$	71
	2-Naphthyl	$\alpha\text{-C}_{10}\text{H}_7\text{N}=\text{NCH}=\text{NOH}$	71
	6-Naphthyl	$\beta\text{-C}_{10}\text{H}_7\text{N}=\text{NCH}=\text{NOH}$	71
Chloromalonic acid	—	$\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{Cl})=\text{NNHC}_6\text{H}_5$ (40–50)	72, 170a
	4-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{N}=\text{NC}(\text{Cl})=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-}p$ (40–50)	72
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{Cl})=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (good)	72
	6-Naphthylamine	$\beta\text{-C}_{10}\text{H}_7\text{N}=\text{NC}(\text{Cl})=\text{NNHC}_{10}\text{H}_7\text{-}\beta$ (poor)	72, 170a
Ethylmalonic acid	—	$\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{N}=\text{NCH}(\text{C}_2\text{H}_5)\text{quant.}$	73
Allylmalonic acid	4-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{N}=\text{NC}(\text{CH}_2\text{CH}=\text{CH}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-}p$ (50)	73
Benzylmalonic acid	—	$\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{CH}_2\text{C}_6\text{H}_5)=\text{NNHC}_6\text{H}_5$ (50)	73
Phenacylmalonic acid	—	$\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{CH}_2\text{COC}_6\text{H}_5)=\text{NNHC}_6\text{H}_5$	202

Malonic Ester	Substituent(s) in Aniline*	R. Malonic Esters	Product (Yield, %)	References
Ethyl hydrogen malonate	4-Nitro		$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (52)	19c
	2-Carboxy-4-chloro		$2,4\text{-HO}_2\text{C}(\text{Cl})\text{C}_6\text{H}_3\text{NHN}=\text{CHCO}_2\text{C}_2\text{H}_5$ (52)	74a
	2-Carboxy-5-chloro		$2,5\text{-HO}_2\text{C}(\text{Cl})\text{C}_6\text{H}_3\text{NHN}=\text{CHCO}_2\text{C}_2\text{H}_5$ (72)	74a
Dimethyl malonate	—		$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	74b, 293
	2-Methyl		$o\text{-CH}_3\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	3-Methyl		$m\text{-CH}_3\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	4-Methyl		$p\text{-CH}_3\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	2-Methoxy		$o\text{-CH}_3\text{OC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	4-Methoxy		$p\text{-CH}_3\text{OC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	2-Nitro		$o\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	3-Nitro		$m\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	4-Nitro		$p\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	2-Carboxy		$o\text{-HO}_2\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	3-Carboxy		$m\text{-HO}_2\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	4-Carboxy		$p\text{-HO}_2\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	2,4-Dimethyl		$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)_2$	293
	Benzidine		$4,4'\text{-Biphenylenedihydrazonobis(dimethyl mesoxalate)}$	294, 295

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

+ This product was obtained when excess diazonium salt was used.

‡ Glyoxylic acid *o*-iodophenylhydrazon was also formed in 8% yield.

§ N,N'-Di-*o*-nitrophenylformazan was also formed in 5% yield.

With excess chloromalonic acid the corresponding 3-aryl-1,3,4-oxadiazol-2-one was formed.

TABLE III—Continued

B. Malonic Esters—Continued

Malonic Ester	Substituent(s) in Aniline*	Product (Yield, %)	References
(Dimethyl malonate) (<i>6</i>)	3,3'-Dimethyl- benzidine	3,3'-Dimethyl-4,4'-biphenylene- dihydrazonobis(dimethyl mesoxalate) (84)	294, 295
	3,3'-Dimethoxy- benzidine	3,3'-Dimethoxy-4,4'-biphenylene- dihydrazonobis(dimethyl mesoxalate) (71)	294, 295
Diethyl malonate	—	$C_6H_5NHN=C(CO_2C_2H_5)_2$	8, 74c, 296
	3-Chloro	$m-ClC_6H_4NHN=C(CO_2C_2H_5)_2$ (78)	74a
	4-Bromo	$p-BrC_6H_4NHN=C(CO_2C_2H_5)_2$	74c
	4-Nitro	$p-O_2NC_6H_4NHN=C(CO_2C_2H_5)_2$ (71)	19c
	3-Carboxy	$m-HO_2CC_6H_4NHN=C(CO_2C_2H_5)_2$	242
	4-Phenyl	$p-C_6H_5C_6H_4NHN=C(CO_2C_2H_5)_2$ (50)	96
	4-Methoxy-2-nitro	$4-CH_3O-2-O_2NC_6H_3NHN=C(CO_2C_2H_5)_2$ (47)	74a
	2-Carboxy-5- chloro	$2-HO_2C-5-ClC_6H_3NHN=C(CO_2C_2H_5)_2$ (67)	74a
	Benzidine	4,4'-Biphenylene- dihydrazonobis(diethyl mesoxalate)	294
	3,3'-Dimethyl- benzidine	3,3'-Dimethyl-4,4'-biphenylene- dihydrazonobis(diethyl mesoxalate) (80)	294
	3,3'-Dimethoxy- benzidine	3,3'-Dimethoxy-4,4'-biphenylene- dihydrazonobis(diethyl mesoxalate)	294
	3,3'-Dicarboxy- benzidine	3,3'-Dicarboxy-4,4'-biphenylene- dihydrazonobis(diethyl mesoxalate)	242
Diethyl chloromalonate	4-Nitro	$p-O_2NC_6H_4N=NCCl(CO_2C_2H_5)_2$ (quant.)	72
Glutaconic acid	—	$C_6H_5N=NCCl(CO_2H)-NHC_6H_5$	297
Diethyl glutaconate	—	$C_6H_5NHN=C(CO_2C_2H_5)CH=CHCO_2C_2H_5$ (77)	298, 76
		$C_6H_5NHN=C(CO_2C_2H_5)CH=CHCO_2C_2H_5N=NCC_6H_5$ (62)	297, 76, 299
	2-Methyl	$o-CH_3C_6H_4NHN=C(CO_2C_2H_5)CH=CHCO_2C_2H_5N=NCC_6H_5$ (61)	76

4-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{CH}_3, p^*$	76
2-Ethoxy	$o\text{-C}_2\text{H}_5\text{OC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{CHCO}_2\text{C}_2\text{H}_5$	76
	$o\text{-C}_2\text{H}_5\text{OC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{-}$	76
	$\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{OC}_2\text{H}_5, o^{\dagger}$	
4-Chloro	$p\text{-ClC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Cl}, p^*$	76
2-Bromo	$o\text{-BrC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Br}, o^*$	76
3-Bromo	$m\text{-BrC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Br}, m^{\dagger}$	76
4-Bromo	$p\text{-BrC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Br}, p^*$	76
4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{CHCO}_2\text{C}_2\text{H}_5$	76
2,4-Dimethyl	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{CHCO}_2\text{C}_2\text{H}_5$	76
	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{-}$	76
	$\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_3(\text{CH}_3)_2, 2,4^{\ddagger}$	76
2,4,6-Trimethyl	$2,4,6\text{-(CH}_3)_3\text{C}_6\text{H}_2\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{CHCO}_2\text{C}_2\text{H}_5$	76
	$2,4,6\text{-(CH}_3)_3\text{C}_6\text{H}_2\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{-}$	76
	$\text{N}=\text{NC}_6\text{H}_2(\text{CH}_3)_3, 2,4,6^{\ddagger}$	

C. Malonic Amides

Malonic Amide	Substituent in Aniline	Product (Yield, %)	References
Malonamide	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CONH}_2)_2$	75
Diethyl N,N'-malonyl-dicarbamate	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2$ (67)	75
	4-Methyl	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_5^{**}$ (74)	75
		$p\text{-CH}_3\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2$	75
		$p\text{-CH}_3\text{C}_6\text{H}_4\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{CH}_3, p^{**}$	75

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† This product was obtained when 2 equivalents of diazonium salt were used.

** This product is obtained when 2 equivalents of diazonium salt are used in the presence of sodium cyanurate.

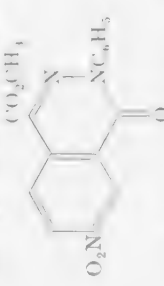
TABLE III—Continued

Malonic Amide	Substituent in Aniline	Product (Yield, %)	References
Diethyl N,N-malonyledicarbonate (Cont.)	2-Nitro	$o\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2$	75
	3-Nitro	$o\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2\text{N}=\text{NC}_6\text{H}_4\text{NO}_2\text{-}o^{**}$	75
	4-Nitro	$m\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2$	75
	—	$p\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2$	75
Malonamide	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CONHCO}_2\text{C}_2\text{H}_5)_2$	300a
$\text{CH}_2(\text{CONHN}=\text{C}(\text{CH}_3)_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NHC}_6\text{H}_5)_2$	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CONHN}=\text{C}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)=\text{NHC}_6\text{H}_5)_2$	280
Ethyl malonamate	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)(\text{CONHC}_6\text{H}_5)$	300b
Methyl N-(α -pyridyl)malonamate	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CO}_2\text{CH}_3)(\text{CONHC}_5\text{H}_4\text{N}-\alpha \text{ (quant.)})$	300b
Ethyl N-(γ -pyridyl)malonamate	—	$\text{C}_6\text{H}_5\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)(\text{CONHC}_5\text{H}_4\text{N}-\gamma)$	300c
Malonamic acid	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{CONH}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (89)	19c
Ethyl malonamate	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{NHN}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)(\text{CONH}_2)$ (36)	19c

Note: References 177-480 are on pp. 136-142.

** This product is obtained when 2 equivalents of diazonium salt are used in the presence of sodium carbonate.

TABLE IV
COUPLING OF DIAZONIUM SALTS WITH ARYLACETIC ACIDS AND ESTERS

Acid or Ester	Substituent(s) in Aniline*	Product (Yield, %)	Reference
2,4-Dinitrophenylacetic acid	4-Bromo	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{Br})\text{N}=\text{NHC}_6\text{H}_5$	77
	2,4-Dichloro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{Cl})_2\text{N}=\text{NHC}_6\text{H}_4\text{Br}$ <i>p</i>	77
	2,4-Dibromo	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{Br})_2\text{N}=\text{NHC}_6\text{H}_3(\text{Cl})_2$ 2,4	77
		$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{Br})_2\text{N}=\text{NHC}_6\text{H}_4\text{Br}$ 2,4	77
		$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_5$	79, 80, 301
Methyl 2,4-dinitrophenylacetate	2-Methyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$ <i>o</i> (98)	79
	4-Methyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3$ <i>p</i> (75)	78, 302
	4-Methoxy	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_4\text{OCH}_3$ <i>p</i>	79
	4-Chloro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_4\text{Cl}$ <i>p</i>	77
	4-Bromo	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_4\text{Br}$ <i>p</i>	77
	4-Acetyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{COCH}_3$ <i>p</i>	78
	2-Nitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2$ <i>o</i> (30)	79
	3-Nitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2$ <i>m</i> (15)	79
	4-Nitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_4\text{NO}_2$ <i>p</i>	79
	2-Carboxy	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_4\text{CO}_2\text{H}$ <i>o</i> (quant.)	79
	4-Carboxy	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_3\text{CO}_2\text{H}$ <i>p</i> (quant.)	78
	4-Sulfo	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_6\text{H}_4\text{SO}_3\text{H}$ <i>p</i>	302
	2,4-Dimethyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)_2\text{N}=\text{NHC}_6\text{H}_3(\text{CH}_3)_2$ 2,4	302
	2,4-Dichloro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)_2\text{N}=\text{NHC}_6\text{H}_3(\text{Cl})_2$ 2,4 (55)	78, 77
	2,4-Dibromo	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3(\text{CO}_2\text{CH}_3)_2\text{N}=\text{NHC}_6\text{H}_3(\text{Br})_2$ 2,4	77
	2,4,6-Trimethyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_2(\text{CH}_3)_3$ 2,4,6 (80)	78
	2,4,6-Trichloro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_2\text{Cl}_3$ 2,4,6 (45)	78
	2-Naphthyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_{10}\text{H}_7$ α	302
	3-Naphthyl	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{C}(\text{CO}_2\text{CH}_3)\text{N}=\text{NHC}_{10}\text{H}_7$ β	79
1,3-bis(4-nitrophenyl)phthalate			79
Methyl 4-oxocyclohexanecarboxylate		$\text{C}_6\text{H}_5\text{NHN}=\text{NCO}_2\text{CH}_2\text{C}_6\text{H}_4\text{CO}_2\text{CH}_3$ 4-NO ₂ 2	79
Homophthalic anhydride		α -Phenyldiazonohomophthalic anhydride	81

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE V

COUPLING OF DIAZONIUM SALTS WITH NITRILES

Substituents in Aniline*	Product (Yield, %)	References
—	$\text{CNC}(\text{CHO})=\text{NNHC}_6\text{H}_5$ (15)	86, 85
4-Bromo	$\text{CNC}(\text{CHO})=\text{NNHC}_6\text{H}_4\text{Br-}p$	86
4-Nitro	$\text{CNC}(\text{CHO})=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (11)	19c
—	$(\text{C}_6\text{H}_5\text{N}=\text{NC}(\text{CN})=\text{NNHC}_6\text{H}_5)$	95a
2-Carboxy	$o\text{-HO}_2\text{CC}_6\text{H}_4\text{N}=\text{NC}(\text{CN})=\text{NNHC}_6\text{H}_4\text{CO}_2\text{H-o}$ (65)	303
4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{CN})=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-}p$	19c
2-Hydroxy 5-chloro	$2\text{-HO-5-Cl-C}_6\text{H}_3\text{N}=\text{NC}(\text{CN})=\text{NNHC}_6\text{H}_3\text{Cl-5-OH-2}$	232a
—	$\text{CNC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_5$	304
2-Methyl	$\text{CNC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-o}$	304
4-Methyl	$\text{CNC}(\text{CO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-}p$	304
Benzidine	4,4'-Biphenylenedihydrazonebis(methyl cyanoglyoxalate)	304
3,3'-Dimethyl- benzidine	3,3'-Dimethyl-4,4'-biphenylenedihydrazonebis(methyl cyanoglyoxalate)	305, 306
3,3'-Dimethoxy- benzidine	3,3'-Dimethoxy-4,4'-biphenylenedihydrazonebis(methyl cyanoglyoxalate)	305, 306
—	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$ (quant.)	82, 74c, 175, 304, 307-309
Ethyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-o}$	82, 304
—	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-}p$	82, 304
2-Methyl	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OCH}_3\text{-o}$	310
4-Methyl	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OCH}_3\text{-}p$	310
2-Methoxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5\text{-}p$	310
4-Methoxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5\text{-}p$	311
4-Ethoxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5\text{-}p$	311
2-Hydroxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OH-o}$	311
3-Hydroxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OH-m}$	311
4-Hydroxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OH-p}$	311
3-Chloro	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{Cl-m}$ (97)	74a

3-Bromo	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{Br-}m$	311
2-Nitro	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{NO}_2\text{-}o$	312
3-Nitro	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{NO}_2\text{-}m$ (76)	312
4-Nitro	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (97)	312
2-Carboxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{CO}_2\text{H-}o$	82
3-Carboxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{CO}_2\text{H-}m$	311
2-Carbomethoxy	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{CO}_2\text{CH}_3\text{-}o$	310
4-Sulfo	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_4\text{SO}_3\text{H-}p$	311
2,4-Dimethyl	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_3(\text{CH}_3)_2\text{-}2,4$	82
2,4,5-Trimethyl	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_2(\text{CH}_3)_3\text{-}2,4,5$	82
2,4-Dichloro	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_3\text{Cl}_2\text{-}2,4$ (96)	313
2,5-Dichloro	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_3\text{Cl}_2\text{-}2,5$ (99)	313
2,5-Dibromo	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_3\text{Br}_2\text{-}2,5$	311
2,4,6-Tribromo	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_2\text{Br}_3\text{-}2,4,6$	311
2-Chloro-4-methyl	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_3\text{Cl-}2\text{-CH}_3\text{-}4$ (71)	238
4-Chloro-2-methyl	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_6\text{H}_3\text{Cl-}4\text{-CH}_3\text{-}2$ (92)	238
α -Naphthylamine	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_{10}\text{H}_7\text{-}\alpha$	311
β -Naphthylamine	$\text{CNC}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{—NNHC}_{10}\text{H}_7\text{-}\beta$	311
Benzidine	4,4'-Biphenylenedihydrazonobis(ethyl cyanoglyoxalate)	305, 310
3,3'-Dimethyl- benzidine	3,3'-Dimethyl-4,4'-biphenylenedihydrazonobis(ethyl cyanoglyoxalate)	305, 310
3,3'-Dimethoxy- benzidine	3,3'-Dimethoxy-4,4'-biphenylenedihydrazonobis(ethyl cyanoglyoxalate)	305, 310
<i>n</i> -Propyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_3\text{H}_7)_2\text{—NNHC}_6\text{H}_5$	314
<i>n</i> -Butyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_4\text{H}_9)_2\text{—NNHC}_6\text{H}_5$	314
<i>n</i> -Amyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_5\text{H}_{11})_2\text{—NNHC}_6\text{H}_5$	314
<i>n</i> -Hexyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_6\text{H}_{13})_2\text{—NNHC}_6\text{H}_5$	315
<i>n</i> -Octyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_8\text{H}_{17})_2\text{—NNHC}_6\text{H}_5$	315
<i>n</i> -Decyl cyanoacetate	$\text{CNC}(\text{CO}_2\text{C}_{10}\text{H}_{21})_2\text{—NNHC}_6\text{H}_5$	19c
Cyanuramide	$\text{CNC}(\text{CONH}_2)_2\text{—NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (56)	19c

Note: References 177-180 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE V—Continued
COUPLING OF DIAZONIUM SALTS WITH NITRILES

Nitrile	Substituent(s) in Aniline*	Product (Yield, %)	References
Octonitrile	4-Methoxy-2-nitro	$C_8H_5N(CCN)(C_6H_5) \rightarrow NNHC_6H_5OC_6H_4-4-NO_2-2$	74a
ethyl isocyanopropionate	4-Nitro	$p-O_2NC_6H_4N \rightarrow NC(C_6H_5)(CN)CO_2C_2H_5^4$	99
ethyl isocyanobutyrate	—	$C_6H_5N \rightarrow NC(C_2H_5)(CN)CO_2C_2H_5^7$	99
ethyl isocyanopropionate	4-Bromo	$p-BrC_6H_4N \rightarrow NC(C_2H_5)(CN)CO_2C_2H_5^8$	99
Malonitrile	—	$C_6H_5NHN=C(CN)COCO_2C_2H_5$ (72)	86, 87
—	4-Bromo	$p-BrC_6H_4NHN=C(CN)COCO_2C_2H_5$ (83)	86, 87
—	—	$C_6H_5NHN=C(CN)_2$	74b, 83
—	4-Nitro	$p-O_2NC_6H_4NHN=C(CN)_2$ (75)	84, 19c
Isocyanindolacetonitrile	—	$C_6H_5N=NC(CN)_2CH_2C_6H_5$ (84)	96
—	4-Nitro	$p-O_2NC_6H_4N \rightarrow NC(CN)_2CH_2C_6H_5$ (87)	96
4-Phenyl	4-Phenyl	$p-C_6H_5C_6H_4N=NC(CN)_2CH_2C_6H_5$ (87)	88, 89
—	—	$C_6H_5NHN=C(NO_2)CN$	19c
—	4-Nitro	$p-O_2NC_6H_4NHN=C(NO_2)CN$ (59)	19c
Methyl isocyanobutyrate	4-Nitro	$p-O_2NC_6H_4N=NC(CN)=NNHC_6H_4NO_2-p$ (72)	19c
Methyl isocyanobutyrate	4-Nitro	$p-O_2NC_6H_4NHN=C(CN)SO_2CH_3$ (63)	19c
p-Nitrophenylacetonitrile	—	$p-O_2NC_6H_4(CCN) \rightarrow NNHC_6H_5$	316
p-Toluidineacetonitrile	—	$CH_3COC(CCN) \rightarrow NNHC_6H_5$	90
p-Cyanobenzoylacetonitrile	—	$CH_3COC(CCN) \rightarrow NNHC_6H_5$	90
p-Toluidineacetonitrile	—	?	90
β -Imino- β -phenyl- propionitrile	—	$C_6H_5COC(CCN) \rightarrow NNHC_6H_5$	90
p-Phenylthioacetonitrile	—	$C_6H_5N \rightarrow C(C_6H_5)(CN) \rightarrow NNHC_6H_5$	91
Phenylacetonitrile	—	$C_6H_5COC(CCN) \rightarrow NNHC_6H_5$	317
2-Methyl	2-Methyl	$C_6H_5COC(CCN) \rightarrow NNHC_6H_4CH_3^o$	317
2-Hydroxy-5-sulfo	2-Hydroxy-5-sulfo	$C_6H_5COC(CCN) \rightarrow NNHC_6H_4(OH)_2SO_3H^o$	91

2-Carboxy-4-sulfo-	$C_6H_5COC(CN) - NNHC_6H_4CO_2H \cdot 2 SO_3H \cdot 4$	94
2-Hydroxy-4-sulfo-	$C_6H_5COC(CN) - NNHC_6H_4OH \cdot 2 SO_3H \cdot 4 CH_3 \cdot 5$	94
5-methyl		
2-Hydroxy-3-sulfo-	$C_6H_5COC(CN) - NNHC_6H_4OH \cdot 2 SO_3H \cdot 3 Cl \cdot 5$	94
5-chloro		
2-Hydroxy-3-sulfo-	$C_6H_5COC(CN) - NNHC_6H_4OH \cdot 2 SO_3H \cdot 3 NO_2 \cdot 5$	94
5-nitro		
2-Hydroxy-3-carboxy-5-sulfo-	$C_6H_5COC(CN) - NNHC_6H_4CO_2H \cdot 3 SO_3H \cdot 5$	94
2-Hydroxy-4-sulfo-	α,β -Dioxo- β -phenylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- β -phenylpropionitrile α -(2-hydroxy-4-sulfo-6-nitro-1-naphthylhydrazine)	94
6-nitro-1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- p -tolylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- o -anisylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- o -ethoxyphenylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- o -propoxyphenylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- o -benzyloxyphenylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		
2-Hydroxy-4-sulfo-	α,β -Dioxo- p -chlorophenylpropionitrile α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
1-naphthylamine		

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

+ Some p - $C_6H_4N(C_6H_5)N \equiv C(CN)(CO_2C_2H_5)$ was also formed.

+ Some $C_6H_5N(C_2H_5)N \equiv C(CN)(CO_2C_2H_5)$ was also formed.

§ Some p - $BrC_6H_4N(C_2H_5)N \equiv C(CN)(CO_2C_2H_5)$ was also formed.

TABLE V—*Continued*
COUPLING OF DIAZONIUM SALTS WITH NITRILES

Nitrile	Substituent(s) in Aniline*	Product (Yield, %)	References
<i>m</i> -Aminobenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- <i>m</i> -aminophenylpropionitrile α -(2-hydroxy-4-sulfo- 1-naphthylhydrazine)	94
<i>m</i> -Nitrobenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- <i>m</i> -nitrophenylpropionitrile α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94
<i>m</i> -Carboxybenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- <i>m</i> -carboxyphenylpropionitrile α -(2-hydroxy-4- sulfo-1-naphthylhydrazine)	94
2,4,4-Dimethoxybenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-2,4-dimethoxyphenylpropionitrile α -(2-hydroxy- 4-sulfo-1-naphthylhydrazine)	94
3,4-Dichlorobenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-3,4-dichlorophenylpropionitrile α -(2-hydroxy- 4-sulfo-1-naphthylhydrazine)	94
3,4,5-Trimethoxybenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-3,4,5-trimethoxyphenylpropionitrile α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94
3,4,5-Triethoxybenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-3,4,5-triethoxyphenylpropionitrile α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94
<i>o</i> - <i>p</i> -Cyanoacetophenyl- benzoylacetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- <i>p</i> -(<i>p</i> -cyanoacetophenyl)phenylpropionitrile α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94
Hexahydrobenzoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxocyclohexylpropionitrile α -(2-hydroxy-4-sulfo- 1-naphthylhydrazine)	94
α -Naphthylacetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-1-naphthylpropionitrile α -(2-hydroxy-4-sulfo- 1-naphthylhydrazine)	94
β -Naphthylacetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-2-naphthylpropionitrile α -(2-hydroxy-4-sulfo- 1-naphthylhydrazine)	94
3-Methoxy-2-naphthoyl- acetone nitrile	2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo-3-methoxy-2-naphthylpropionitrile α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94

2-Hydroxy-4-sulfo- 6-nitro-1- naphthylamine	α,β -Dioxo-3-methoxy-2-naphthylpropionitrile- α -(2-hydroxy-4-sulfo-6-nitro-1-naphthylhydrazine)	94
2-Hydroxy-3-nitro- 4-sulfo	α,β -Dioxo-3-methoxy-2-naphthylpropionitrile- α -(2-hydroxy-3-nitro-4-sulfophenylhydrazine)	94
2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- β -(5,6,7,8-tetrahydro-2-naphthyl)-propionitrile- α -(2-hydroxy-4-sulfo-1-naphthylhydrazine)	94
2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- β -(5-acenaphthyl)propionitrile- α -(2-hydroxy-4-sulfo- 1-naphthylhydrazine)	94
2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- β -(2-thienyl)propionitrile- α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94
2-Hydroxy-4-sulfo- 1-naphthylamine	α,β -Dioxo- β -(2-furyl)propionitrile- α -(2-hydroxy-4-sulfo-1- naphthylhydrazine)	94
2-Carboxy-4-sulfo	α,β -Dioxo- β -(2-furyl)propionitrile- α -(2-carboxy-4- sulphophenylhydrazine)	94
2-Carboxy-3-sulfo- 4-chloro	α,β -Dioxo- β -(2-furyl)propionitrile- α -(2-carboxy-3-sulfo-4- chlorophenylhydrazine)	94
2-Hydroxy-4-sulfo- 6-nitro-1- naphthylamine	α,β -Dioxo- β -(2-furyl)propionitrile- α -(2-hydroxy-4-sulfo-6- nitro-1-naphthylhydrazine)	94
2-Carboxy-4-sulfo	4,4'-Biphenylene-bis-(α,β -dioxopropionitrile) $\alpha\alpha'$ -di-(2-carboxy-4-sulfophenylhydrazine)	94
2-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})-\text{NHC}_6\text{H}_5$	92
3-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})-\text{NHC}_6\text{H}_4\text{CH}_3-o$	92
2-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})-\text{NHC}_6\text{H}_4\text{CH}_3-m$	92
4-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})-\text{NHC}_6\text{H}_4\text{OC}_6\text{H}_5-o$	92
	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})-\text{NHC}_6\text{H}_4\text{OC}_6\text{H}_5-p$	92

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE V—Continued
COUPLING OF DIAZONIUM SALTS WITH NITRILES

Nitrile	Substituent(s) in Aniline*	Product (Yield, %)	References
Phenylsulfonylacetamide (<i>Conf.</i>)	4-Ethoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5$ - <i>p</i>	92
2-Tolylsulfonylacetamide	2,4-Dimethyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_3(\text{CH}_3)_2$ -2,4 $p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_5$	92
	2-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i>	92
	3-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>m</i>	92
	4-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i>	92
	2-Methoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>o</i>	92
	4-Methoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>p</i>	92
	4-Ethoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5$ - <i>p</i>	92
	2,4-Dimethyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_3(\text{CH}_3)_2$ -2,4 $p\text{-BrC}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_5$	92
<i>p</i> -Bromophenylsulfonylacetamide	—	—	93
	4-Ethoxy	$p\text{-BrC}_6\text{H}_4\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5$ - <i>p</i> $\alpha\text{-C}_{10}\text{H}_7\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_5$ (67)	93
α -Naphthylsulfonylacetamide	—	—	93
	2-Methyl	$\alpha\text{-C}_{10}\text{H}_7\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i>	93
	4-Methyl	$\alpha\text{-C}_{10}\text{H}_7\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i>	93
	4-Methoxy	$\alpha\text{-C}_{10}\text{H}_7\text{SO}_2\text{C}(\text{CN})=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5$ - <i>p</i>	93

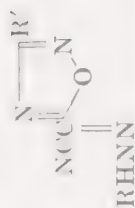
β -Naphthylsulfonyl- propionitrile	—	β -C ₁₀ H ₇ SO ₂ C(CN)N=NNHC ₆ H ₅	93
3-Methyl	—	β -C ₁₀ H ₇ SO ₂ C(CN)N=NNHC ₆ H ₄ CH ₃ - <i>m</i>	93
4-Methyl	—	β -C ₁₀ H ₇ SO ₂ C(CN)N=NNHC ₆ H ₄ CH ₃ - <i>p</i>	93
4-Ethoxy	—	β -C ₁₀ H ₇ SO ₂ C(CN)N=NNHC ₆ H ₄ OC ₂ H ₅ - <i>p</i>	93
α -Thienylsulfonylpropionitrile	—	C ₆ H ₅ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₅	93
4-Methyl	—	C ₆ H ₅ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₄ CH ₃ - <i>p</i>	93
4-Methoxy	—	C ₆ H ₅ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₄ OC ₂ H ₅ - <i>p</i>	93
4-Ethoxy	—	C ₆ H ₅ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₄ OC ₂ H ₅ - <i>p</i>	93
α - <i>p</i> -Chlorophenylsulfonyl- propionitrile	—	<i>p</i> -ClC ₆ H ₄ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₅	93
α - <i>p</i> -Bromophenylsulfonyl- propionitrile	β -Naphthylamine	<i>p</i> -ClC ₆ H ₄ SO ₂ C(CN)(CH ₃)N=NC ₁₀ H ₇ - β	93
α -(β -Naphthylsulfonyl)- propionitrile	4-Methyl	<i>p</i> -BrC ₆ H ₄ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₄ CH ₃ - <i>p</i>	93
α -(β -Naphthylsulfonyl)- propionitrile	4-Methoxy	<i>p</i> -BrC ₆ H ₄ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₄ OC ₂ H ₅ - <i>p</i>	93
α -Phenoxyacetyl- β -amino- β - phenylpropionitrile	4-Methyl	β -C ₁₀ H ₇ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₅	93
β -Phenoxyacetimido- β - phenylpropionitrile	—	β -C ₁₀ H ₇ SO ₂ C(CN)(CH ₃)N=NC ₆ H ₄ CH ₃ - <i>p</i>	318
	—	C ₆ H ₅ OC ₂ H ₂ COOC(CN)(C ₆ H ₅)(C ₆ H ₅)C(=NNHC ₆ H ₅)	319

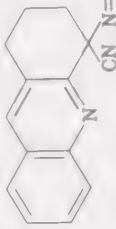
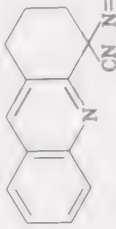
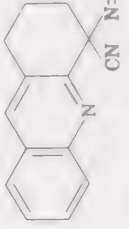
Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE V—Continued

COUPLING OF DIAZONIUM SALTS WITH NITRILES



Nitrile	Substituent in Aniline	R	R'	Yield, %	References
(3- <i>p</i> -Tolyl-1,2,4-oxadiazol-5-yl)- acetonitrile	—	Phenyl	<i>p</i> -Tolyl	20	32
(3- <i>m</i> -Nitrophenyl-1,2,4-oxa- diazol-5-yl)acetonitrile	2-Methoxy	<i>o</i> -Anisyl	<i>p</i> -Tolyl	20	32
	4-Nitro	<i>p</i> -Nitrophenyl	<i>p</i> -Tolyl	20	32
	4-Diethylamino	<i>p</i> -Diethylaminophenyl	<i>p</i> -Tolyl	20	32
	4-Diethylamino	<i>p</i> -Diethylaminophenyl	<i>m</i> -Nitrophenyl	20	32
(3- <i>m</i> -Nitrophenyl-1,2,4-oxa- diazol-5-yl)acetonitrile	4-Methoxy			50	98
1,2,3,4-Tetrahydroacridine- 4-carbonitrile	4-Methoxy			56	98
2,3-Dimethyl-5-cyclopenta[<i>b</i>]- quinoline-3-carbonitrile	4-Bromo			61	98

Yield	Substituent in Aniline	Product (Yield, %)	References
Benzothiazole-2-acetonitrile	4-Bromo	 (17)	36a
3-Methylquinoxaline-2-acetonitrile	4-Chloro	 (87)	36a

TABLE VI

COUPLING OF DIAZONIUM SALTS WITH SULFONES

Sulfone	Substituent(s) in Aniline*	Product (Yield, %)	References
Bis(methylsulfonyl)methane	—	$(\text{CH}_3\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_5$ (56)	101
	2-Methyl	$(\text{CH}_3\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i> (43)	101
	4-Methyl	$(\text{CH}_3\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i> (36)	101
	4-Nitro	$(\text{CH}_3\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> †	19c
Bis(ethylsulfonyl)methane	—	$(\text{C}_2\text{H}_5\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_5$ (43)	101
	2-Methyl	$(\text{C}_2\text{H}_5\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i> (48)	101
	4-Methyl	$(\text{C}_2\text{H}_5\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i> (33)	101
	4-Nitro	$(\text{C}_2\text{H}_5\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> †	19c
Methyl (methylsulfonyl)methyl sulfoxide	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{SO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> †	19c
Ethyl (methylsulfonyl)acetate	4-Nitro	$\text{C}_2\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> (79)	19c
2-Methylsulfonylacetamide	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{SO}_2\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> (54)	19c
Methyl nitromethyl sulfone	4-Nitro	$\text{CH}_3\text{SO}_2\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> (35)	19c
Bis(phenylsulfonyl)methane	4-Nitro	$(\text{C}_6\text{H}_5\text{SO}_2)_2\text{C}=\text{NNHC}_6\text{H}_4\text{NO}_2$ - <i>p</i> †	19c
Bis(methylsulfonyl)methylhiomethane	—	$(\text{CH}_3\text{SO}_2)_2\text{C}(\text{SCH}_3)\text{N}=\text{NC}_6\text{H}_5$ (66)	320
Phenylsulfonylacetic acid	2-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{N}=\text{NC}_6\text{H}_4\text{CH}_3$ - <i>o</i>) $\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i>	92
	2-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{N}=\text{NC}_6\text{H}_4\text{OCH}_3$ - <i>o</i>) $\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>o</i>	92
	—	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_5$	92
Ethyl phenylsulfonylacetate	2-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>o</i>	92
	3-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>m</i>	92
	4-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{CH}_3$ - <i>p</i>	92
	2-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>o</i>	92
	4-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OCH}_3$ - <i>p</i>	92
	4-Ethoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5$ - <i>p</i>	92
	2,4-Dimethyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)=\text{NNHC}_6\text{H}_3(\text{CH}_3)_2$ -2,4	92

Ethyl <i>p</i> -tolylsulfonylacetate		
2-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_5$	92
3-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}o$	92
4-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}m$	92
2-Methoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}p$	92
4-Methoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_4\text{OCCH}_3\text{-}o$	92
4-Ethoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_4\text{OCCH}_3\text{-}p$	92
2,4-Dimethyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)\text{--NNHC}_6\text{H}_3(\text{CH}_3)_2\text{-}2,4$	92
Phenylsulfonylacetamide		
2-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_5$	92
3-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}o$	92
4-Methyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}m$	92
2-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}p$	92
4-Methoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{OCCH}_3\text{-}o$	92
4-Ethoxy	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{OCCH}_3\text{-}p$	92
2,4-Dimethyl	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_3(\text{CH}_3)_2\text{-}2,4$	92
<i>p</i> -Tolylsulfonylacetamide		
2-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_5$	92
3-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}o$	92
4-Methyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}m$	92
2-Methoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{CH}_3\text{-}p$	92
4-Methoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{OCCH}_3\text{-}o$	92
4-Ethoxy	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_4\text{OCCH}_3\text{-}p$	92
2,4-Dimethyl	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{CONH}_2)\text{--NNHC}_6\text{H}_3(\text{CH}_3)_2\text{-}2,4$	92
Phenylsulfonylbutromethane	$\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{NO}_2)\text{--NNHC}_6\text{H}_5$	102
<i>p</i> -Tolylsulfonylbutromethane	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{NO}_2)\text{--NNHC}_6\text{H}_4\text{NO}_2\text{-}p$ (22)	19c

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† In addition, some 5-hydroxy-1,3-bis-(*p*-nitrophenyl)tetrazolium betaine was formed.

TABLE VI—Continued
COUPLING OF DIAZONIUM SALTS WITH SULFONES

Sulfone	Substituent (s) in Aniline*	Product (Yield, %)	References
<i>p</i> -Bromophenyl sulfonylethylmethane	—	<i>p</i> -BrC ₆ H ₄ SO ₂ C(NO ₂)=NNHC ₆ H ₅	102
<i>m</i> -Nitrobenzyl phenyl sulfone	—	<i>m</i> -O ₂ NC ₆ H ₄ C(SO ₂ C ₆ H ₅)=NNHC ₆ H ₅	102
Sulfazone, i.e.,	5-Sulfo-1-naphthylamine	2-(5-Sulfo-1-naphthylazo)sulfazone	103
	8-Hydroxy-6-sulfo-1-naphthylamine	2-(8-Hydroxy-6-sulfo-1-naphthylazo)sulfazone	103
	3-Sulfo-4-(<i>p</i> -sulphophenylazo)naphthylamine	2-[3-Sulfo-4-(<i>p</i> -sulphophenylazo)phenylazo]sulfazone	103
	4-[<i>p</i> -(4-Hydroxy-3-carboxyphenylazo)-phenyl]carboxyphenylazo	2-[<i>p</i> -(4-Hydroxy-3-carboxyphenylazo)-phenyl]phenylazo)sulfazone	103
Sulfazone-7-sulfonylactic acid	4-Sulfo	2-(<i>p</i> -Sulphophenylazo)sulfazone-7-sulfonylactic acid	321
	3-Carboxy-4-hydroxy	2-(3-Carboxy-4-hydroxyphenylazo)sulfazone-7-sulfonylactic acid	321
	1-Sulfo-1-naphthylamine	2-(4-Sulfo-1-naphthylazo)sulfazone-7-sulfonylactic acid	321

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE VII
COUPLING OF DIAZONIUM SALTS WITH NITRO COMPOUNDS

Nitro Compound	Substituent(s) in Aniline*	Product (Yield, %)	References
Nitromethane	—	$C_6H_5NHN=CHNO_2$	104, 105, 107, 322
		$C_6H_5N=NC(NO_2)=NNHC_6H_5$ (56)	20, 3, 104– 107, 323
2-Methyl		$o\text{-}CH_3C_6H_4N=NC(NO_2)=NNHC_6H_4CH_3\text{-}o$	106
4-Methyl		$p\text{-}CH_3C_6H_4N=NC(NO_2)=NNHC_6H_4CH_3\text{-}p$	106
2-Ethoxy		$o\text{-}C_2H_5OC_6H_4N=NC(NO_2)=NNHC_6H_4OC_2H_5\text{-}o$	20
4-Bromo		$p\text{-}BrC_6H_4N=NC(NO_2)=NNHC_6H_4Br\text{-}p$	106
2-Nitro		$o\text{-}O_2NC_6H_4NHN=CHNO_2$ (77)	323a, 323b
4-Nitro		$p\text{-}O_2NC_6H_4N=NC(NO_2)=NNHC_6H_4NO_2\text{-}p$	106
		$p\text{-}O_2NC_6H_4NHN=CHNO_2$ (6)	171, 324
2-Formyl		$o\text{-}HCO_2C_6H_4NHN=CHNO_2$ (57)	167d
2-Acetyl		$o\text{-}CH_3COC_6H_4NHN=CHNO_2$ (98)	167d
2-Carboxy		$o\text{-}HO_2CC_6H_4NHN=CHNO_2$ (73)	167d
2-Carboethoxy		$o\text{-}CH_3O_2CC_6H_4NHN=CHNO_2$ (95)	167d
4-Carboethoxy		$p\text{-}C_2H_5O_2CC_6H_4NHN=CHNO_2$ (80)	171
4-Sulfo		$p\text{-}HO_3SC_6H_4N=NC(NO_2)=NNHC_6H_4SO_3H\text{-}p$	325
4-Sulfamyl		$p\text{-}H_2NSO_2C_6H_4N=NC(NO_2)=NNHC_6H_4SO_2NH_2\text{-}p$	106
2,4-Dimethyl		2,4-(CH_3) $_2C_6H_3N=NC(NO_2)=NNHC_6H_3(CH_3)_2\text{-}2,4$ (20)	170
2-Phenyl		$o\text{-}C_6H_5C_6H_4N=NC(NO_2)=NNHC_6H_4C_6H_5\text{-}o$	20
3-Phenyl		$m\text{-}C_6H_5C_6H_4N=NC(NO_2)=NNHC_6H_4C_6H_5\text{-}m$	20
4-Phenyl		$p\text{-}C_6H_5C_6H_4N=NC(NO_2)=NNHC_6H_4C_6H_5\text{-}p$	106
4-Phenoxy		$p\text{-}C_6H_5OC_6H_4N=NC(NO_2)=NNHC_6H_4OC_6H_5\text{-}p$	20

Note: References 177–480 are on pp. 136–142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE VII—*Continued*
COUPLING OF DIAZONIUM SALTS WITH NITRO COMPOUNDS

Nitro Compound	Substituent(s) in Aniline*	Product (Yield, %)	References
8-Nitroethane (<i>Contd.</i>)	α -Naphthylamine	α -C ₁₀ H ₇ N=NC(NO ₂)=NNHC ₁₀ H ₇ - α	106
	β -Naphthylamine	β -C ₁₀ H ₇ N=NC(NO ₂)=NNHC ₁₀ H ₇ - β (63)	106
	2-Phenylthio	<i>o</i> -C ₆ H ₅ SC ₆ H ₄ N=NC(NO ₂)=NNHC ₆ H ₄ SC ₆ H ₅ - <i>o</i>	20
	2-(<i>p</i> -Anisyloxy)	N,N'-Di- <i>o</i> -(<i>p</i> -anisyloxy)phenyl-C-nitroformazan†	20
	2-Phenoxy-4-phenyl	N,N'-Di-(2-phenoxy-4-phenyl)phenyl-C-nitroformazan†	20
	2-Phenylthio-4-phenyl	N,N'-Di-(2-phenylthio-4-phenyl)phenyl-C-nitroformazan†	20
Nitrobenzene	—	CH ₃ C(NO ₂)=NNHC ₆ H ₅ (quant.)	326, 1, 2, 107, 171, 324
	2-Methyl	CH ₃ C(NO ₂)=NNHC ₆ H ₄ CH ₃ - <i>o</i>	327
	4-Methyl	CH ₃ C(NO ₂)=NNHC ₆ H ₄ CH ₃ - <i>p</i>	324, 327
	4-Chloro	CH ₃ C(NO ₂)=NNHC ₆ H ₄ Cl- <i>p</i> (quant.)	176b
	4-Bromo	CH ₃ C(NO ₂)=NNHC ₆ H ₄ Br- <i>p</i>	328
	3-Nitro	CH ₃ C(NO ₂)=NNHC ₆ H ₄ NO ₂ - <i>m</i>	329
	4-Nitro	CH ₃ C(NO ₂)=NNHC ₆ H ₄ NO ₂ - <i>p</i>	324
	4-Sulfo	CH ₃ C(NO ₂)=NNHC ₆ H ₄ SO ₃ H- <i>p</i>	325
	2,4-Dichloro	CH ₃ C(NO ₂)=NNHC ₆ H ₃ Cl ₂ -2,4 (95)	330
	2,4,6-Trichloro	CH ₃ C(NO ₂)=NNHC ₆ H ₂ Cl ₃ -2,4,6†	330, 331
	2,4,6-Tribromo	CH ₃ C(NO ₂)=NNHC ₆ H ₂ Br ₃ -2,4,6 (49)†	331
	α -Naphthylamine	CH ₃ C(NO ₂)=NNHC ₁₀ H ₇ - α (5)	332
1-Nitropropane	β -Naphthylamine	CH ₃ C(NO ₂)=NNHC ₁₀ H ₇ - β	324, 332
	—	C ₂ H ₅ C(NO ₂)=NNHC ₆ H ₅ (87)	326, 4, 107, 324
	4-Methyl	C ₂ H ₅ C(NO ₂)=NNHC ₆ H ₄ CH ₃ - <i>p</i>	324
	4-Nitro	C ₂ H ₅ C(NO ₂)=NNHC ₆ H ₄ NO ₂ - <i>p</i>	324
β -Naphthylamine	—	C ₂ H ₅ C(NO ₂)=NNHC ₁₀ H ₇ - β	324

1-Nitro- <i>n</i> -propane	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_5$	2, 333
4-Methyl	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{CH}_3-p$	333
4-Chloro	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{Cl}-p$	333
4-Bromo	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{Br}-p$	333
2-Nitro	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{NO}_2-o$	333
3-Nitro	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{NO}_2-m$	333
4-Nitro	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{NO}_2-p$	324, 333
2-Carboxy	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{CO}_2\text{H}-o$	333
4-Carboxy	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{CO}_2\text{H}-p$	333
4-Sulfo	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{SO}_3\text{H}-p$	325
4-Acetamido	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4\text{NHCOCH}_3-p$	333
2,5-Dichloro	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_3\text{Cl}_2-2,5$	333
2-Methyl-5-nitro	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_3\text{CH}_3-2-\text{NO}_2-5$	333
2,4,6-Tribromo	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_2\text{Br}_3-2,4,6$	333
2-Naphthylamine	$(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_{10}\text{H}_7-\beta$	324, 333
Benzidine	$[(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{N}=\text{NC}_6\text{H}_4]_2$	333
4-Phenylazo	$p-\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{CH}_3)_2\text{NO}_2$	333
	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	334
2-Methyl	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3-o$	334
4-Methyl	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3-p$	334
4-Methoxy	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{OCH}_3-p$	334
4-Ethoxy	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{OC}_2\text{H}_5-p$	334
4-Chloro	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{Cl}-p$	334
3-Bromo	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{Br}-m$	334
4-Carboxy	$\text{CH}_2=\text{CHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CO}_2\text{H}-p$	334
1-Nitro- <i>n</i> -butane	$n-\text{C}_4\text{H}_7\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† The formazan structure is $\text{H}_2\text{NN}=\text{CHN}=\text{NH}$.

‡ In addition, some diarylazonitroethane was formed.

TABLE VII—Continued

COUPLING OF DIAZONIUM SALTS WITH NITRO COMPOUNDS

Nitro Compound	Substituent(s) in Aniline*	Product (Yield, %)	References
2-Nitro- <i>n</i> -butane	3-Nitro	$C_2H_5C(NO_2)(CH_3)N=NC_6H_4NO_2-m$	3333
	4-Carboxy	$C_2H_5C(NO_2)(CH_3)N=NC_6H_4CO_2H-p$	3333
	2,5-Dichloro	$C_2H_5C(NO_2)(CH_3)N=NC_6H_3Cl_2-2,5$	3333
	2-Methyl-5-nitro	$C_2H_5C(NO_2)(CH_3)N=NC_6H_3CH_3-2-NO_2-5$	3333
	2,4,6-Tribromo	$C_2H_5C(NO_2)(CH_3)N=NC_6H_2Br_3-2,4,6$	3333
	4-Phenylazo	$C_2H_5C(NO_2)(CH_3)N=NC_6H_4(N=NC_6H_5)-p$	3333
2-Methyl-1-nitropropane	—	$(CH_3)_2CHC(NO_2)=NNHC_6H_5$	5
1-Nitro- <i>n</i> -pentane	4-Sulfo	$(CH_3)_2CHC(NO_2)=NNHC_6H_4SO_3H-p$	325
1-Nitromethane	—	$n-C_4H_9C(NO_2)=NNHC_6H_5$ (90-100)	326
	—	$C_6H_5N=NC(H)NO_2$	335
1,2-Dinitropropane	4-Nitro	$p-O_2NC_6H_4NHN=C(NO_2)_2$ (37)	19c
	—	$C_6H_5NHN=C(NO_2)(H_2C(NO_2)=NNHC_6H_5$	336
	4-Methyl	$p-CH_3C_6H_4NHN=C(NO_2)(H_2C(NO_2)=NNHC_6H_4CH_3-p$	336
	4-Methoxy	$p-CH_3OC_6H_4NHN=C(NO_2)(H_2C(NO_2)=NNHC_6H_4OCH_3-p$	336
1,5-Dinitro- <i>n</i> -pentane	—	$C_6H_5NHN=C(NO_2)(CH_2)_3C(NO_2)=NNHC_6H_5$	337
1,7-Dinitro- <i>n</i> -heptane	—	$C_6H_5NHN=C(NO_2)(CH_2)_5C(NO_2)=NNHC_6H_5$	338
1,6-Dinitromethane	—	$IC(NO_2)=NNHC_6H_5$	339
	4-Methyl	$IC(NO_2)=NNHC_6H_4CH_3-p$	339
Methazonic acid	—	$C_6H_5NHN=C(NO_2)CH=NOH$	340
	4-Methyl	$p-CH_3C_6H_4NHN=C(NO_2)CH=NOH$	340
Nitroacetamide	—	$C_6H_5NHN=C(NO_2)CONH_2$	89
	4-Nitro	$p-O_2NC_6H_4NHN=C(NO_2)CONH_2$ (66)	19c
Methyl nitroacetate	—	$C_6H_5NHN=C(NO_2)CO_2CH_3$ (56)	341
Ethyl nitroacetate	—	$C_6H_5NHN=C(NO_2)CO_2C_2H_5$	342
	4-Nitro	$p-O_2NC_6H_4NHN=C(NO_2)CO_2C_2H_5$	342

4-Nitro-1-butanefulfonic acid	1-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{N}(\text{NO}_2)(\text{C}_2\text{H}_5)(\text{CH}_3\text{SO}_3\text{H})$ (51)	343
	4-Phenylazo	$p\text{-(C}_6\text{H}_5\text{N}=\text{N})(\text{C}_6\text{H}_4\text{N}=\text{N}(\text{NO}_2)(\text{C}_2\text{H}_5)(\text{CH}_3\text{SO}_3\text{H}))$ (56)	343
	3,3'-Dimethoxy- benzidine	2,2'-(3,3'-Dimethoxy-4,4'-biphenylene)diazobis-2-nitro-1-butanefulfonic acid] (77)	343
2-Nitroethanol	4-Sulfo	$\text{HOCH}_2\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$ (94)	107, 344
	—	$\text{HOCH}_2\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{SO}_3\text{H-}p$	344
2-Nitropropanol	—	$\text{CH}_3\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$ (78)	107
1-Nitro-2-propanol	—	$\text{CH}_3\text{CHOHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
2-Nitro-1-butanol	—	$\text{C}_2\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
	4-Methyl	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{CH}_3\text{-}p\text{\S}$	108
	2-Chloro	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Cl-}o\text{\S}$	108
	4-Chloro	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Cl-}p\text{\S}$ (56)	108
	—	$\text{C}_2\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{Cl-}p$	108
	2-Bromo	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Br-}o\text{\S}$	108
	4-Bromo	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_4\text{Br-}p\text{\S}$	108
	—	$\text{C}_2\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{Br-}p$	108
	2,5-Dichloro	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_3(\text{Cl}_2\text{-2,5}\text{\S})$	108
	2-Methyl-4-nitro	$\text{C}_2\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_3(\text{CH}_3\text{-2-NO}_2\text{-4})$	108
	5-Methyl-3-nitro	$\text{HOCH}_2\text{C}(\text{NO}_2)(\text{C}_2\text{H}_5)\text{N}=\text{NC}_6\text{H}_3\text{CH}_3\text{-5-NO}_2\text{-3}\text{\S}$	108
1-Nitro-2-butanol	—	$\text{C}_2\text{H}_5\text{CHOHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
2-Nitro-2-butanol	—	$\text{CH}_3\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
1,1,1-Trichloro-3-nitro-2-propanol	—	$\text{Cl}_3\text{CCHOHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

§ This product was obtained by acidification of the reaction mixture.

|| This product was obtained when the alkaline reaction mixture was left for several days.

TABLE VII—Continued

COUPLING OF DIAZONIUM SALTS WITH NITRO COMPOUNDS

Nitro Compound	Substituent(s) in Aniline*	Product (Yield, %)	References
1,1,1-Trichloro-3-nitro-2-propyl acetate	—	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	345
2-Nitro-1,3-propanediol	2-Methyl	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-o}$	345
2-Nitro-1-pentanol	3-Methyl	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-m}$	345
1-Nitro-2-pentanol	4-Methyl	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-p}$	345
1-Nitro-2-hexanol	4-Chloro	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{Cl-p}$	345
2-Nitro-1-phenylethanol	4-Nitro	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-p}$	345
3,3,4-Trichloro-1-nitro-2-pentyl acetate	2,4-Dichloro	$\text{Cl}_3\text{CCH}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_3\text{Cl}_2\text{-2,4}$ $\text{HOCH}_2\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$ (97)	345
	—	$n\text{-C}_3\text{H}_7\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
	—	$n\text{-C}_3\text{H}_7\text{CHOHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
	—	$n\text{-C}_4\text{H}_9\text{CHOHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
	—	$\text{C}_6\text{H}_5\text{CHOHC}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	107
	—	$\text{CH}_3\text{CHClCCl}_2\text{C}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$	345
	4-Methyl	$\text{CH}_3\text{CHClCCl}_2\text{C}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-p}$	345
	4-Chloro	$\text{CH}_3\text{CHClCCl}_2\text{C}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_3\text{Cl-p}$	345
	4-Nitro	$\text{CH}_3\text{CHClCCl}_2\text{C}(\text{O}_2\text{CCH}_3)\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-p}$	345
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NC}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{NO}_2\text{-p}$ $\text{C}_6\text{H}_5\text{CHOHC}(\text{NO}_2)\text{CH}(\text{C}_6\text{H}_3\text{Cl}_2\text{NO}_2)=\text{NNHC}_6\text{H}_5$	346
1-Benzoyl-2-nitroethanol	—	$\text{C}_6\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$ (80)	347
2,4-Dinitro-1,3-diphenyl-1-butanol	—	$\text{C}_6\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{CH}_3\text{-p}$ (40)	171, 348, 349
<i>o</i> -Nitrotoluene	4-Methyl	$\text{C}_6\text{H}_5\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{OCH}_3\text{-p}$ (33)	171
	4-Methoxy	$\text{C}_6\text{H}_3\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_4\text{OC}_4\text{H}_9\text{-p}$ (34)	171
	4-Butoxy		

1-Benzoyloxy	$C_6H_5C(NO_2)=NNHC_6H_4OCH_2C_6H_5-p$ (39)	171
3-Nitro	$C_6H_5C(NO_2)=NNHC_6H_4NO_2-m$ (quant.)	350
4-Nitro	$C_6H_5C(NO_2)=NNHC_6H_4NO_2-p$	111, 172, 350
4-Phenyl	$C_6H_5C(NO_2)=NNHC_6H_4C_6H_5-p$ (33)	171
2,4-Dinitro	$C_6H_5C(NO_2)=NNHC_6H_3(NO_2)_2-4$	350
2-Methyl-4-nitro	$C_6H_5C(NO_2)=NNHC_6H_3CH_3-2-NO_2-4$	172
4-Methyl-2-nitro	$C_6H_5C(NO_2)=NNHC_6H_3CH_3-4-NO_2-2$	172
2-Chloro-4-nitro	$C_6H_5C(NO_2)=NNHC_6H_3Cl-2-NO_2-4$	172
β -Naphthylamine	$C_6H_5C(NO_2)=NNHC_{10}H_7-\beta$ (34)	171
2-(<i>o</i> -Nitrophenyl)	$C_6H_5C(NO_2)=NNHC_6H_4(C_6H_4NO_2-o)-o$ (55)	323a
4-Chloro-2-(4-chloro-2-nitro-phenyl)	$C_6H_5C(NO_2)=NNHC_6H_3Br-4-(C_6H_3Br-4-NO_2-2)-2$	323a
—		
2-Methyl	$C_6H_5C(CN)=NNHC_6H_4NO_2-p$	114
4-Methyl	$C_6H_5C(CN)=NNHC_6H_3CH_3-2-NO_2-4$	114
2-Chloro	$C_6H_5C(CN)=NNHC_6H_3CH_3-4-NO_2-2$	114
4-Chloro	$C_6H_5C(CN)=NNHC_6H_3Cl-2-NO_2-4$	114
2-Nitro	$C_6H_5C(CN)=NNHC_6H_3Cl-4-NO_2-2$	114
4-Nitro	$C_6H_5C(CN)=NNHC_6H_3(NO_2)_2-2,4$	114
—	$p-CH_3OC_6H_4(CNO_2)=NNHC_6H_5$	351
<i>p</i> -Methoxy- α -nitrotoluene	$p-ClC_6H_4(CNO_2)=NNHC_6H_4(C_6H_4NO_2-o)-o$ (75)	323a
<i>p</i> -Chloro- α -nitrotoluene	$m-O_2NC_6H_4(CNO_2)=NNHC_6H_5$ (quant.)	352
α,m -Dinitrotoluene	$p-O_2NC_6H_4(CNO_2)=NNHC_6H_5$	352
α,p -Dinitrotoluene	$p-O_2NC_6H_4(CNO_2)=NNHC_6H_4NO_2-p$	342
4-Nitro		

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE VII—*Continued*
COUPLING OF DIAZONIUM SALTS WITH NITRO COMPOUNDS

Nitro Compound	Substituent(s) in Aniline*	Product (Yield, %)	References
<i>o</i> -Nitroacetophenone	—	$C_6H_5COC(NO_2)=NNHC_6H_5$ (60)	353
	4-Chloro	$C_6H_5COC(NO_2)=NNHC_6H_4Cl-p$	353
	4-Bromo	$C_6H_5COC(NO_2)=NNHC_6H_4Br-p$	353
	2-Nitro	$C_6H_5COC(NO_2)=NNHC_6H_4NO_2-o$	353
	4-Nitro	$C_6H_5COC(NO_2)=NNHC_6H_4NO_2-p$	342, 353
	2,4-Dichloro	$C_6H_5COC(NO_2)=NNHC_6H_3Cl_2-2,4$	353
	2,5-Dichloro	$C_6H_5COC(NO_2)=NNHC_6H_3Cl_2-2,5$	353
	2,4-Dibromo	$C_6H_5COC(NO_2)=NNHC_6H_3Br_2-2,4$	353
	2,4,6-Tribromo	$C_6H_5COC(NO_2)=NNHC_6H_2Br_3-2,4,6$	353
	2,4,5-Tribromo	$C_6H_5COC(NO_2)=NNHC_6H_2Br_3-2,4,5$	353
	—	$C_6H_5(CH_2)_2C(NO_2)=NNHC_6H_5$	354
	—	$(C_6H_5)_2C=NNHC_6H_4NO_2-p$	112, 113
	—	$C_6H_5C(NO_2)=NNHC_6H_4NO_2-p$	109, 111, 355
	2-Methyl	$C_6H_5C(NO_2)=NNHC_6H_3CH_3-2-NO_2-4$	109, 356
	4-Methyl	$C_6H_5CON=NC_6H_4CH_3-p$	356
	2-Chloro	$C_6H_5CON=NC_6H_3Cl-2-NO_2-4$	109, 356
	4-Chloro	$C_6H_5CON=NC_6H_4Cl-p$	356
	2-Bromo	$C_6H_5C(NO_2)=NNHC_6H_3Br-2-NO_2-4$	109, 356
	4-Bromo	$C_6H_5CON=NC_6H_4Br-p$	356, 357
	2,4-Dimethyl	$C_6H_5CON=NC_6H_3(CH_3)_2-2,4$	110
1-Nitro-3-phenylpropane			
Diphenylbutromethane			
<i>o,o'</i> -Dinitrotoluene			

2-Methyl-1-nitro	C_6H_5CON	$NC_6H_4CH_2-2-NO_2-4$	110
4-Methyl-2-nitro	C_6H_5CON	$NC_6H_4CH_2-1-NO_2-2$	110
1-Methyl-3-nitro	C_6H_5CON	$NC_6H_4CH_2-1-NO_2-3$	110
2,4,6-Tribromo	C_6H_5CON	$NC_6H_2Br_3-2,4,6$	110
s,s-Dinitro-4-xylene	$p-CH_3C_6H_4(NO_2)_2$	$NNHC_6H_4NO_2-p$	109, 358
s,s-Dinitro-2-methoxytoluene	$p-CH_3OC_6H_4(NO_2)_2$	$NNHC_6H_4NO_2-p$	109, 358
4-(2-Nitropropyl)morpholine	—	4-(2-Nitro-2-phenylazopropyl)morpholine (22)	176a
—	4-Chloro	4-[2-Nitro-2-(p-chlorophenylazo)propyl]morpholine (26)	176a
—	2-Nitro	4-[2-Nitro-2-(o-nitrophenylazo)propyl]morpholine (32)	176a
—	3-Nitro	4-[2-Nitro-2-(m-nitrophenylazo)propyl]morpholine (41)	176a
—	4-Nitro	4-[2-Nitro-2-(p-nitrophenylazo)propyl]morpholine (46)	176a
—	2-Carboxy	4-[2-Nitro-2-(o-carboxyphenylazo)propyl]morpholine (13)	176a
—	4-Carboxy	4-[2-Nitro-2-(p-carboxyphenylazo)propyl]morpholine (26)	176a
—	2,4-Dichloro	4-[2-Nitro-2-(2,4-dichlorophenylazo)propyl]morpholine (48)	176a
—	β -Naphthylamine	4-(2-Nitro-2- β -naphthylazopropyl)morpholine (25)	176a
—	4-Phenylazo	4-[2-Nitro-2-(p-phenylazophenylazo)propyl]morpholine (80)	176a
—	4-Chloro	2-(p-Chlorophenylazo)-2-nitrotributylamine (7)	176a
1-Di-n-butylamino-2-nitro-butane	—	2- β -Naphthylazo-2-nitrotributylamine (17)	176a
—	β -Naphthylamine	2,3-Diphenyl-1,4-dihydrazono-1,4-dinitrobutane (89)	359
—	—	2,3-Di-(3,4-methylenedioxyphenyl)-1,4-dihydrazono-1,4-dinitrobutane	359
Nitromethyl p-tolyl sulfoxide	4-Nitro	$p-CH_3C_6H_4SOC(NO_2)=NNHC_6H_4NO_2-p$ (43)	19c

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE VIII

COUPLING OF DIAZONIUM SALTS WITH HYDROCARBONS

A. *Unsaturated Hydrocarbons*

Hydrocarbon	Substituent(s) in Aniline*	Product (Yield, %)	References
2-Methylpropene	1-Amino	$(\text{CH}_3)_2\text{C}=\text{CHN}=\text{NC}_6\text{H}_4\text{N}=\text{NCH}=\text{C}(\text{CH}_3)_2$	116
1,3-Butadiene	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{NCH}=\text{C}(\text{CH}_3)_2$	116
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NCH}=\text{CHCH}=\text{CH}_2$	360
2-Methyl-2-butene	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{NCH}=\text{CHCH}=\text{CH}_2$ (13)	115
	4-Amino	$(\text{CH}_3)_2\text{C}=\text{C}(\text{CH}_3)\text{N}=\text{NC}_6\text{H}_4\text{N}=\text{N}(\text{CH}_3)=\text{C}(\text{CH}_3)_2$	116
	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{N}(\text{CH}_3)=\text{C}(\text{CH}_3)_2$	116
1,3-Pentadiene	4-Amino	$\text{CH}_2=\text{CHCH}=\text{C}(\text{CH}_3)\text{N}=\text{NC}_6\text{H}_4\text{N}=\text{N}$ $\text{NC}(\text{CH}_3)=\text{CHCH}=\text{CH}_2$	116
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{N}(\text{CH}_3)=\text{CHCH}=\text{CH}_2$	115, 116
2-Methyl-1,3-butadiene	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{N}(\text{CH}_3)=\text{CHCH}=\text{CH}_2$	115, 116
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NCH}=\text{C}(\text{CH}_3)\text{CH}=\text{CH}_2$	361a
2,4-Hexadiene	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{N}(\text{CH}_3)=\text{CHCH}=\text{CH}_2$	115
	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{N}(\text{CH}_3)=\text{CHCH}=\text{CHCH}_3$	116, 360
	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{N}(\text{CH}_3)=\text{CHCH}=\text{CHCH}_3$	116
2-Methyl-2,4-pentadiene	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{NCH}=\text{CHCH}=\text{C}(\text{CH}_3)_2$ (49)	361b
2,5-Dimethyl-1,3-butadiene	4-Nitro	$p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{NCH}=\text{C}(\text{CH}_3)\text{C}(\text{CH}_3)=\text{CH}_2$ (47)	115
	2,4-Dinitro	$2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{NCH}=\text{C}(\text{CH}_3)\text{C}(\text{CH}_3)=\text{CH}_2$	115
Cyclopentadiene	—	1-Phenylazocyclopentadiene (small)	117, 362
	4-Nitro	1-(<i>p</i> -Nitrophenylazocyclopentadiene	118
2,4-Cyclopentadiene-1-carboxylic acid	2,4-Dinitro	1-(2,4-Dinitrophenylazocyclopentadiene	118
2,5-Cyclopentadiene-1-carboxylic acid	2-Hydroxy-5-sulfo	1-(2-Hydroxy-5-sulfophenylazo)-2,4-cyclopentadiene-1-carboxylic acid (40)	363
2,5-Dimethyl-2,4-hexadiene	4-Amino	3,3'-(<i>p</i> -Phenylenediazobis-(2,5-dimethyl-2,4-hexadiene)	116
	4-Nitro	3-(<i>p</i> -Nitrophenylazo)-2,5-dimethyl-2,4-hexadiene	116

2,4-Dinitro	3-(2,4-Dinitrophenylazo)-2,5-dimethyl-2,4-hexadiene	116
2,4-Dinitro	1-(2,4-Dinitrophenylazo)indene	118
2,4-Dinitro	p -CH ₃ OC ₆ H ₄ CH=NNHC ₆ H ₃ (NO ₂) ₂ -2,4 (21)	124
4-Nitro	C ₆ H ₅ COC ₆ H=NNHC ₆ H ₄ NO ₂ - p (13)	124
4-Nitro	p -CH ₃ OC ₆ H ₄ COCH=NNHC ₆ H ₄ NO ₂ - p (33)	124
2,4-Dinitro	p -CH ₃ OC ₆ H ₄ COCH=NNHC ₆ H ₃ (NO ₂) ₂ -2,4 (69)	124
4-Nitro	p -CH ₃ OC ₆ H ₄ CH=NNHC ₆ H ₄ NO ₂ - p (71)†	127
2,4-Dinitro	p -CH ₃ OC ₆ H ₄ CH=NNHC ₆ H ₃ (NO ₂) ₂ -2,4 (62)†	127
4-Nitro	o -HOC ₆ H ₄ CH=NNHC ₆ H ₄ NO ₂ - p (25)†	130
4-Nitro	p -HOC ₆ H ₄ CH=NNHC ₆ H ₄ NO ₂ - p (60)†	130
4-Nitro	Piperonal p -nitrophenylhydrazone (72)†	127
2,4-Dinitro	Piperonal 2,4-dinitrophenylhydrazone†	127
4-Nitro	Vanillin p -nitrophenylhydrazone (86)†	128
2,4-Dinitro	Vanillin 2,4-dinitrophenylhydrazone†	128
4-Nitro	Apiolaldehyde p -nitrophenylhydrazone†	127
4-Nitro	p -(CH ₃) ₂ NC ₆ H ₄ CH=NNHC ₆ H ₄ NO ₂ - p ††	129
2,4-Dinitro	(C ₆ H ₅) ₂ C=CHN=NC ₆ H ₃ (NO ₂) ₂ -2,4	14
4-(p -Phenyl)- mercaptobenzoyl	$(p$ -CH ₃ C ₆ H ₄) ₂ C=CHN=NC ₆ H ₄ (OC ₆ H ₄ SC ₆ H ₅ - p)- p	13
4-Nitro	$(p$ -CH ₃ OC ₆ H ₄) ₂ C=CHN=NC ₆ H ₄ NO ₂ - p (40)	14
4-(p -Phenyl)- mercaptobenzoyl	$(p$ -CH ₃ OC ₆ H ₄) ₂ C=CHN=NC ₆ H ₄ (OC ₆ H ₄ SC ₆ H ₅ - p)- p	13
2,4-Dinitro	p -CH ₃ OC ₆ H ₄ (C ₆ H ₅)=CHN=NC ₆ H ₅	14
	p -CH ₃ OC ₆ H ₄ C(C ₆ H ₅)=CHN=NC ₆ H ₃ (NO ₂) ₂ -2,4 (40)	14

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

† These products were obtained by the addition of the dry diazonium salt to an ethanolic solution of the reactant.

‡ When an alcoholic solution of the reactant was added to the dry diazonium salt, the entire side chain was eliminated to give a nearly quantitative yield of N,N -dimethyl- p -(p -nitrophenylazo)aniline.³⁶⁴

TABLE VIII—Continued
A. Unsaturated Hydrocarbons—Continued

Hydrocarbon	Substituent(s) in Aniline*	Product (Yield, %)	References
1,3-Bis(p-dimethylamino-phenyl)ethylene	—	$[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)_2\text{C}=\text{CHN}=\text{NC}_6\text{H}_5]$	14
1-Phenyl-1-p-dimethylamino-phenylethylene	4-Nitro 2,4-Dinitro 1-Aminoanthraquinone	$[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)_2\text{C}=\text{CHN}=\text{NC}_6\text{H}_4\text{NO}_2-p]$ $[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)_2\text{C}=\text{CHN}=\text{NC}_6\text{H}_3(\text{NO}_2)_2-2,4]$ $[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)_2\text{C}=\text{CHN}=\text{NC}_{14}\text{H}_7\text{O}_2 (88)]$	14 14 14 14
1-Phenyl-1-p-dimethylamino-phenylethylene	—	$[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)(\text{C}_6\text{H}_5)=\text{CHN}=\text{NC}_6\text{H}_5]$	14
1-Phenyl-1,3-butadiene	4-Nitro 2,4-Dinitro	$[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)(\text{C}_6\text{H}_5)=\text{CHN}=\text{NC}_6\text{H}_4\text{NO}_2-p]$	14
2,3-Diphenyl-1,3-butadiene	4-Nitro 2,4-Dinitro	$[p-(\text{CH}_3)_2\text{N}(\text{C}_6\text{H}_4)(\text{C}_6\text{H}_5)=\text{CHN}=\text{NC}_6\text{H}_3(\text{NO}_2)_2-2,4]$ $\text{C}_6\text{H}_5\text{CH}=\text{CHCH}=\text{CHN}=\text{NC}_6\text{H}_4\text{NO}_2-p$ $2,4-(\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{N}=\text{NCH}=\text{C}(\text{C}_6\text{H}_5)\text{C}(\text{C}_6\text{H}_5)=\text{CH}_2$	14 365 366

B. Compounds Containing a Reactive Methyl Group

Reactive Methyl Compound	Substituent(s) in Aniline	Product (Yield, %)	References
α -Picoline	4-Nitro	α -Picolinaldehyde <i>p</i> -nitrophenylhydrazone (58)	132
2,4,6-Trinitrotoluene	4-Nitro	2,4,6-Trinitrobenzaldehyde <i>p</i> -nitrophenylhydrazone (86)	132
2-Methylimidazole	4-Nitro	Imidazole-2-carboxaldehyde <i>p</i> -nitrophenylhydrazone (64)	132
2,6-Triethyl-3,6-dicarboxypyridine	4-Nitro	3,5-Dicarboxy-6-methylpyridine-2-carboxaldehyde <i>p</i> -nitrophenylhydrazone (94)	132
N -Methylquinazolinum iodide	4-Nitro	1,2-Dihydro-1-methyl-2-phenylazomethylenequinoline 1,2-Dihydro-1-methyl-2-(<i>p</i> -nitrophenylazomethylene)-quinoline	133, 134 133, 134

N-Methylpyridinium methanesulfate	4-Nitro	1,2-Dihydro-1-methyl-2-(<i>p</i> -nitrophenylazomethylene)- quinoline	132 <i>g</i>
	2,5-Dichloro	1,2-Dihydro-1-methyl-2-(2,5-dichlorophenylazomethylene)- quinoline	132 <i>g</i>
	2-Methoxy-5-chloro	1,2-Dihydro-1-methyl-2-(2-methoxy-5-chlorophenylazo- methylene)quinoline	132 <i>g</i>
	2-Methoxy-4-nitro	1,2-Dihydro-1-methyl-2-(2-methoxy-4-nitrophenylazo- methylene)quinoline	132 <i>g</i>
	4-Nitro	1,4-Dihydro-1-ethyl-4-(<i>p</i> -nitrophenylazomethylene)- quinoline	132 <i>g</i>
N-Ethylpyridinium iodide	2,5-Dichloro	1,4-Dihydro-1-ethyl-4-(2,5-dichlorophenylazomethylene)- quinoline	132 <i>g</i>
	2-Methoxy-5-chloro	1,4-Dihydro-1-ethyl-4-(2-methoxy-5-chlorophenylazo- methylene)quinoline	132 <i>g</i>
	2-Methoxy-4-nitro	1,4-Dihydro-1-ethyl-4-(2-methoxy-4-nitrophenylazo- methylene)quinoline	132 <i>g</i>
2,3,4-Trimethylindolenine	—	3,3-Dimethylindolenine-2-carboxaldehyde phenyl- hydrazone (60–90)	132 <i>a</i>
	4-Chloro	3,3-Dimethylindolenine-2-carboxaldehyde <i>p</i> -chloro- phenylhydrazone (60–90)	132 <i>a</i>
	4-Nitro	3,3-Dimethylindolenine-2-carboxaldehyde <i>p</i> -nitrophenyl- hydrazone	132 <i>a</i>
1,3,4-Trifluoromethylindolenine iodide	—	1,2-Dihydro-2-phenylazomethylene-1,3,3-trimethylindoline	133, 135
	4-Nitro	1,2-Dihydro-2-(<i>p</i> -nitrophenylazomethylene)-1,3,3- trimethylindoline	133, 135
	4-Iodo	1,2-Dihydro-2-(<i>p</i> -iodophenylazomethylene)-1,3,3- trimethylindoline	133
	2-Methoxy-4-nitro	1,2-Dihydro-2-(2-methoxy-4-nitrophenylazomethylene)- 1,3,3-trimethylindoline	135

Note: References 177–480 are on pp. 136–142.

— The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE VIII—Continued
B. Compounds Containing a Reactive Methyl Group—Continued

Reactive Methyl Compound	Substituent(s) in Aniline	Product (Yield, %)	References
2-Methylbenzothiazole	4-Nitro	Benzothiazole-2-carboxaldehyde <i>p</i> -nitrophenylhydrazine (30)	366a, b
2,3-Dimethylbenzothiazolium iodide	—	2-[Bis(phenylazo)methylene]-3-methylbenzothiazoline	132c
—	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3-methylbenzothiazoline	132c
2,3-Dimethylbenzothiazolium mesito-sulfate	—	2-[Bis-(phenylazo)methylene]-3-methylbenzothiazoline (80)	132d
4-Methyl	4-Methoxy	2-[Bis-(<i>p</i> -tolylazo)methylene]-3-methylbenzothiazoline	132d
4-Chloro	4-Chloro	2-[Bis-(<i>p</i> -anisylazo)methylene]-3-methylbenzothiazoline	132d
—	2-Nitro	2-[Bis-(<i>p</i> -chlorophenylazo)methylene]-3-methylbenzothiazoline	132b, 132d
—	4-Nitro	2-[Bis-(<i>o</i> -nitrophenylazo)methylene]-3-methylbenzothiazoline	132d
—	4-Sulfo	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3-methylbenzothiazoline	132g
2,5-Dichloro	2-Methoxy-4-nitro	2-[Bis-(<i>p</i> -sulfophenylazo)methylene]-3-methylbenzothiazoline	132b, 132d
—	4-Chloro	2-[Bis-(2,5-dichlorophenylazo)methylene]-3-methylbenzothiazoline	132d
—	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3-methylbenzothiazoline	132g
—	—	2-[Bis-(<i>p</i> -chlorophenylazo)methylene]-3-ethylbenzothiazoline	132b
—	—	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3-ethylbenzothiazoline	132b, 132c

2,3,6-Trimethylbenzo- thiazolium methosulfate	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3,6-dimethylbenzo- thiazoline	132 <i>e</i>
2,3-Dimethyl-6-methoxybenzo- thiazolium methosulfate	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-6-methoxy-3-methyl- benzothiazoline	132 <i>e</i>
2-Methyl-3-ethyl-5,6-dimethoxy- benzothiazolium methosulfate	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3-ethyl-5,6-dimethoxy- benzothiazoline	132 <i>e</i>
1,2,3-Trimethylbenzo- imidazolium methosulfate	—	2-[Bis(phenylazo)methylene]-1,3-dimethylbenzimidazolium	132 <i>e</i>
4-Chloro	4-Chloro	2-[Bis-(<i>p</i> -chlorophenylazo)methylene]-1,3-dimethylbenzimi- dazolium	132 <i>e</i>
1,2,3-Trimethyl-5-nitrobenzi- midazolium iodide	4-Nitro	1-Methyl-2-(<i>p</i> -nitrophenylazomethyl)-5-nitrobenzi- midazole (50)	132 <i>f</i>
1-Phenyl-2,3-dimethyl-5-nitro- benzimidazolium iodide	4-Nitro	1-Phenyl-2-(<i>p</i> -nitrophenylazomethyl)-5-nitrobenzi- midazole	132 <i>f</i>
1-Phenyl-2-methyl-3-ethyl-5- nitrobenzimidazolium iodide	4-Nitro	1-Phenyl-2-(<i>p</i> -nitrophenylazomethyl)-5-nitrobenzi- midazole	132 <i>f</i>
2,3-Dimethylbenzoselenazolium methosulfate	—	2-[Bis(phenylazo)methylene]-3-methylbenzoselenazolium	132 <i>e</i>
4-Chloro	4-Chloro	2-[Bis-(<i>p</i> -chlorophenylazo)methylene]-3-methylbenzo- selenazolium	132 <i>e</i>
4-Nitro	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-3-methylbenzo- selenazolium	132 <i>e</i>
1,2-Dimethylnaphtho[1,2]- thiazolium methosulfate	—	2-[Bis(phenylazo)methylene]-1-methylnaphtho[1,2]- thiazoline	132 <i>e</i>
4-Chloro	4-Chloro	2-[Bis-(<i>p</i> -chlorophenylazo)methylene]-1-methylnaphtho- [1,2]thiazoline	132 <i>e</i>
4-Nitro	4-Nitro	2-[Bis-(<i>p</i> -nitrophenylazo)methylene]-1-methylnaphtho- [1,2]thiazoline	132 <i>e</i>
4-Nitro	4-Nitro	1,2-Dihydro-1-methyl-2-(<i>p</i> -nitrophenylazomethylene)- 3,3-diethylindoline	133, 135

Note: References 177-480 are on pp. 136-142.

TABLE VIII—Continued

B. Compounds Containing a Reactive Methyl Group—Continued		
Reactive Methyl Compound	Substituent(s) in Aniline	Product (Yield, %)
o-Methylacridine	—	Acridine-9-carboxaldehyde phenylhydrazone
	2-Methyl	Acridine-9-carboxaldehyde o-tolylhydrazone
	3-Methyl	Acridine-9-carboxaldehyde m-tolylhydrazone
	4-Methyl	Acridine-9-carboxaldehyde p-tolylhydrazone
	2-Methoxy	Acridine-9-carboxaldehyde o-anisylhydrazone
	4-Methoxy	Acridine-9-carboxaldehyde p-anisylhydrazone
	4-Hydroxy	Acridine-9-carboxaldehyde p-hydroxyphenylhydrazone
	4-Chloro	Acridine-9-carboxaldehyde p-chlorophenylhydrazone
	4-Iodo	Acridine-9-carboxaldehyde p-iodophenylhydrazone
	2-Nitro	Acridine-9-carboxaldehyde o-nitrophenylhydrazone
	3-Nitro	Acridine-9-carboxaldehyde m-nitrophenylhydrazone
	4-Nitro	Acridine-9-carboxaldehyde p-nitrophenylhydrazone
	2-Carboxy	Acridine-9-carboxaldehyde o-carboxyphenylhydrazone
	3-Carboxy	Acridine-9-carboxaldehyde m-carboxyphenylhydrazone
	4-Carboxy	Acridine-9-carboxaldehyde p-carboxyphenylhydrazone
	4-Sulfo	Acridine-9-carboxaldehyde p-sulfoxyphenylhydrazone
	2,4-Dimethyl	Acridine-9-carboxaldehyde 2,4-dimethylphenylhydrazone
	2,4-Dinitro	Acridine-9-carboxaldehyde 2,4-dinitrophenylhydrazone
	2,5-Dimethoxy-4-phenylamino	Acridine-9-carboxaldehyde 2,5-dimethoxy-4-(phenylamino)phenylhydrazone (43)
	—	9,10-Dihydro-9-methyl-10-phenylazomethyleneacridine
9,10-Dimethylacridinium methanesulfate	—	—
	4-Nitro	9,10-Dihydro-9-methyl-10-(p-nitrophenylazomethylene)-acridine

References

131
131
131
131
131
131
131
131
131
131
131
131
131
131
131
131
131
132
1414, 132^a

2,3-Dichloro	9,10-Dihydro-9-methyl-10-(2,5-dichlorophenylazo)-methylenecacridine	132 <i>g</i>
2,4-Dinitro	9,10-Dihydro-9-methyl-10-(2,4-dinitrophenylazo)-methylenecacridine	14
2-Methoxy-5-chloro	9,10-Dihydro-9-methyl-10-(2-methoxy-5-chlorophenylazo)-methylenecacridine	132 <i>g</i>
2-Methoxy-4-nitro	9,10-Dihydro-9-methyl-10-(2-methoxy-4-nitrophenylazo)-methylenecacridine	132 <i>g</i>
2-Acetamido-9-methylacridine	2-Acetamidoacridine-9-carboxaldehyde phenylhydrazone (66)	132
4-Nitro	2-Acetamidoacridine-9-carboxaldehyde <i>p</i> -nitrophenylhydrazone (55)	132
9-Methylxanthylum perchlorate	Xanthene-9-carboxaldehyde phenylhydrazone	14
4-Nitro	Xanthene-9-carboxaldehyde <i>p</i> -nitrophenylhydrazone	14
2,4-Dinitro	Xanthene-9-carboxaldehyde 2,4-dinitrophenylhydrazone	14
—	Thioxanthene-9-carboxaldehyde phenylhydrazone	14
4-Nitro	Thioxanthene-9-carboxaldehyde <i>p</i> -nitrophenylhydrazone	14
2,4-Dinitro	Thioxanthene-9-carboxaldehyde 2,4-dinitrophenylhydrazone	14
—	1-Phenyl-3-methyl-4- α -(phenylazomethyl)ethylidene-2-pyrazolin-5-one (57)	135 <i>a</i>
4-Nitro	1-Phenyl-3-methyl-4- α -(<i>p</i> -nitrophenylazomethyl)-ethylidene-2-pyrazolin-5-one (76)	135 <i>a</i>
3-Carboxy	1-Phenyl-3-methyl-4- α -(<i>m</i> -carboxyphenylazomethyl)-ethylidene-2-pyrazolin-5-one (62)	135 <i>a</i>
2,5-Dichloro	1-Phenyl-3-methyl-4- α -(2,5-dichlorophenylazomethyl)-ethylidene-2-pyrazolin-5-one (51)	135 <i>a</i>

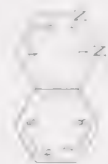
TABLE VIII—Continued

B. Compounds Containing a Reactive Methyl Group—Continued

Parentive Methyl Compound	Substituent(s) in Aniline	Product (Yield, %)	References
1-Phenyl-3-methyl-4- α -methyl- benzylidene-2-pyrazolin-5-one	—	1-Phenyl-3-methyl-4- α -phenylazomethylbenzylidene-2-pyrazolin-5-one (70)	135a
	4-Nitro	1-Phenyl-3-methyl-4- α -(<i>p</i> -nitrophenylazomethyl)benzylidene-2-pyrazolin-5-one (73)	135a
	2-Carboxy	1-Phenyl-3-methyl-4- α -(<i>o</i> -carboxyphenylazomethyl)benzylidene-2-pyrazolin-5-one (82)	135a
	2,5-Dichloro	1-Phenyl-3-methyl-4- α -(2,5-dichlorophenylazomethyl)benzylidene-2-pyrazolin-5-one (87)	135a
	4-Chloro-2-nitro	1-Phenyl-3-methyl-4- α -(4-chloro-2-nitrophenylazomethyl)benzylidene-2-pyrazolin-5-one (47)	135a
1-Phenyl-3-methyl-4-(α -methyl- methylidenebenzylidene-2-pyrazolin-5-one	4-Nitro	1-Phenyl-3-methyl-4-[α -(<i>p</i> -nitrophenylazomethyl)- <i>m</i> -nitrobenzylidene]-2-pyrazolin-5-one (52)	135a

C. Cinnolines from *o*-Aminophenylethylenes

Substituent(s) in Cinnoline (Yield, %)



Amine

o-Aniline- α -methylstyrene
 2-(2'-Amino-5'-chlorophenyl)propene
 2-(2'-Amino-4'-chlorophenyl)propene

4-Methyl (90)

6-Chloro-4-methyl (28)

7-Chloro-4-methyl (55)

References

368, 369

369

369

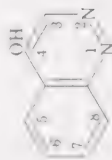
2-(2-Amino-3-chlorophenyl)propene	370
2-(2-Amino-3-methoxyphenyl)propene	167c, 167a
2-(2-Amino-4-carboxyphenyl)propene	369, 119
2-(2-Amino-4-methoxyphenyl)styrene	120
2-(2-Amino-4-methoxyphenyl)-6-bromostyrene	120
2-(2-Amino-4-methoxyphenyl)-7-methylstyrene	120
2-(2-Amino-4-methoxyphenyl)- <i>p</i> -methoxystyrene	121
2-(2-Pyridyl)- α -aminostyrene	123
2-(2-Amino-5-bromophenyl)styrene	122
2-(2-Amino-5-methoxyphenyl)styrene	167a
2-(2-Amino-5-chlorophenyl)-2-hydroxystyrene	122
2-(2-Amino-5-chlorophenyl)-2-hydroxy-5-methylstyrene	122
1-(<i>o</i> -Aminophenyl)-1-phenylpropene	371, 120
1-(<i>o</i> -Aminophenyl)-1- <i>p</i> -anisylpropene	371
2-(<i>o</i> -Aminophenyl)- β -phenylstyrene	372
2-(<i>o</i> -Aminophenyl)- β -(<i>p</i> -anisyl)styrene	372
α -(<i>o</i> -Aminophenyl)- β -benzylstyrene	372
2-(<i>o</i> -Aminophenyl)- β -1-naphthylstyrene	372
2-(<i>o</i> -Aminophenyl)- β -2-pyridylstyrene	123
2-(<i>o</i> -Aminophenyl)- β -(2-pyridyl)- <i>p</i> -methoxystyrene	123
2-Hydroxy-5-aminopipidine	373
8-Chloro-4-methyl (29)	
8-Methoxy-4-methyl (72)	
7-Carboxy-4-methyl (79)	
4-Phenyl (quant.)	
4-Phenyl (22)	
4-(<i>p</i> -Tolyl)	
4-(<i>p</i> -Anisyl)	
4-(2'-Pyridyl) (25)	
6-Bromo-4-phenyl	
8-Methoxy-4-phenyl (86)	
6-Chloro-4-(<i>p</i> -hydroxyphenyl)	
6-Chloro-4-(2-hydroxy-5-methylphenyl)	
3-Methyl-4-phenyl (84)	
4-(<i>p</i> -Anisyl)-3-methyl (90)	
3,4-Diphenyl (quant.)	
4-(<i>p</i> -Anisyl)-3-phenyl (98)	
3-Benzyl-4-phenyl (quant.)	
3-(α -Naphthyl)-4-phenyl*	
4-Phenyl-3-(2-pyridyl) (25)	
4-(<i>p</i> -Anisyl)-3-(2-pyridyl) (70)	
5-Hydroxy-3-pyridyl 4,3,2- <i>del</i>	

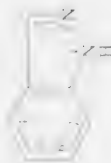
Note: References 177-480 are on pp. 136-142.

* 2-Phenylchrysene is also formed.

TABLE VIII—Continued
D. 4-Hydroxycinnolines from *o*-Aminophenylacetylenes

Amine	Substituent(s) in	(Yield, %)	References
<i>o</i> -Aminophenylacetylene		—	125
2-Amino-5-methoxyphenylacetylene		6-Methoxy	125
2-Amino-5-chlorophenylacetylene		6-Chloro (20*)	23
2-Amino-5-bromophenylacetylene		6-Bromo (20*)	23
1-(<i>o</i> -Aminophenyl)-2-phenylacetylene		3-Phenyl (55)	23
1-(2-Amino-4'-methoxyphenyl)-2-phenylacetylene		6-Methoxy-3-phenyl	23
<i>o</i> -Aminophenylpropionic acid		3-Carboxy (60)	367, 125, 126
2-Amino-5-chlorophenylpropionic acid		3-Carboxy-6-chloro (66)	23
2-Amino-5-bromophenylpropionic acid		3-Carboxy-6-bromo (66)	23
2-Amino-5-methoxyphenylpropionic acid		3-Carboxy-6-methoxy (68*)	125
2-Amino-4,5-methylenedioxyphenylpropionic acid		3-Carboxy-6,7-methylenedioxy (37*)	125



E. Indazoles from *o*-ToluidinesProduct, Substituent(s)
in Indazole

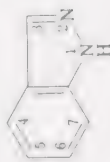
Reactant, Substituent(s) in Aniline	(Yield, %)	References
2-Methyl	— (3-5)	136, 138
2-Cyanoethyl	3-Cyano (71)	95 <i>b</i> , 168
2-Methyl-3-nitro	4-Nitro (96-98)	137, 376
2,4-Dimethyl	5-Methyl	136
2-Methyl-4-nitro	5-Nitro (82-90)	137, 138, 376
2-Methyl-5-nitro	6-Nitro (90-96)	137, 374, 375, 376
2-Methyl-6-nitro	7-Nitro (80)	137, 376
2,4,6-Trimethyl	5,7-Dimethyl (small)	136
2,4-Dinitro-6-methyl	5,7-Dinitro (34-38)	378
2,3-Dimethyl-4-nitro	4-Methyl-5-nitro (79-86)	137
2,3-Dimethyl-5-nitro	4-Methyl-6-nitro (94)	137
2,3-Dimethyl-6-nitro	4-Methyl-7-nitro (100)	137
2,4-Dimethyl-3-nitro	5-Methyl-4-nitro (79)	137
2,4-Dimethyl-5-nitro	5-Methyl-6-nitro (75-80)	137
2,4-Dimethyl-6-nitro	5-Methyl-7-nitro (48-53)	137, 377
2,5-Dimethyl-3-nitro	6-Methyl-4-nitro (93)	137
2,5-Dimethyl-4-nitro	6-Methyl-5-nitro (83)	137

Note: References 177-480 are on pp. 136-142.

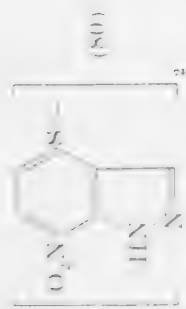
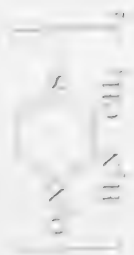
* This is an over-all yield from the nitro compound.

TABLE VIII—Continued
E. Indazoles from *o*-Toluidines—Continued

Reactant, Substituent(s) in Aniline	Product, Substituent(s) in Indazole	(Yield, %)	References
2,5-Dimethyl-6-nitro		6-Methyl-7-nitro (81)	137
2,6-Dimethyl-3-nitro		7-Methyl-4-(or 6-)nitro (100)	137
3-Chloro-2-methyl-4-nitro		4-Chloro-5-nitro (86)	380
3-Chloro-2-methyl-6-nitro		4-Chloro-7-nitro	379
4-Chloro-2-methyl-6-nitro		5-Chloro-7-nitro	379
2,6-Dinitro-6-methyl		7-Chloro-6-nitro* (85)	380
6-Methoxy-2-methyl-6-nitro		1-Methoxy-7-nitro	379
6-Methoxy-6-methyl-2-nitro		6-Methoxy-7-nitro (83)	383
3-Diethylsulfamyl-2-methyl-6-nitro		4-Diethylsulfamyl-7-nitro	379
2,4,6-Trimethyl-3-nitro		5,6-Dimethyl-4-nitro (58)	137
5,6-Trimethyl-2-nitro		5,6-Dimethyl-7-nitro (20)	137
3,4,6-Trimethyl-3-nitro		5,7-Dimethyl-4-(or 6-)nitro (100)	137
2,4-Dimethyl-3,5-dinitro		5-Methyl-4,6-dinitro (80)	137
2,6-Dimethyl-3,5-dinitro		7-Methyl-4,6-dinitro (86)	137
2,4-Dimethyl-2,4-dinitro		6-Methyl-5,7-dinitro (100)	137
2,4-Dinitro-6-methyl-3-sulfo		5,7-Dinitro-6-sulfo	381
2,4,6-Trimethyl-3-amino		5,7-Dimethyl-4-triazol†	382
2,6-Toluidine-3,4,6-trimethyl		5,6-Dimethyl-4,7-dinitro (75, 85)	137
3,6-Toluidine-2,4,6-trimethyl		5,7-Dimethyl-4,6-dinitro (100)	137

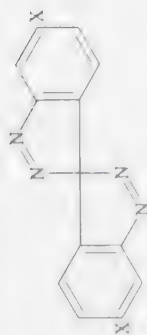


Reference)



380)

Substituents X in



- 13s-(2-amino-4-chlorophenyl)methane
- 13s-(2-amino-4-cyanophenyl)methane
- 13s-(2-amino-4-acetylphenyl)methane
- 13s-(2-amino-4-acetamidophenyl)methane
- 13s-(2-amino-4-carboxyphenyl)methane
- 13s-(2-amino-4-carbethoxyphenyl)methane

384
385
385
385
385
386

Note: References 177-480 are on pp. 136-142.

* One nitro group was replaced by chlorine when the diazotization was run in hydrochloric acid.

† This product was prepared by tetrazotizing the amine and reacting the tetrazonium salt with sodium azide.

TABLE IX

COUPLING OF DIAZONIUM SALTS WITH HYDRAZONES

A. Simple Hydrazones



R	R'	R''	Yield, %	References
H	Cholyl (C ₂₃ H ₃₉ O ₂)	C ₆ H ₅	—	387
O ₂ N	C ₆ H ₅	C ₆ H ₅	—	322
CH ₃	C ₆ H ₅	C ₆ H ₅	88	139, 144, 388
CH ₃	C ₆ H ₅	<i>o</i> -O ₂ NC ₆ H ₄	—	144
CH ₃	C ₆ H ₅	<i>m</i> -O ₂ NC ₆ H ₄	—	144
CH ₃	C ₆ H ₅	<i>p</i> -O ₂ NC ₆ H ₄	Quant.	139, 144
CH ₃	C ₆ H ₅	<i>p</i> -HO ₃ SC ₆ H ₄	Quant.	389
CH ₃	C ₆ H ₅	<i>p</i> -(C ₆ H ₅ CH=CH)C ₆ H ₄	68	389a
CH ₃	C ₆ H ₅	<i>p</i> -(C ₆ H ₅ CH=CH)C ₆ H ₄	—	389b
CH ₃	C ₆ H ₅	<i>p</i> - <i>p</i> -O ₂ NC ₆ H ₄ CH=CH)C ₆ H ₄	16	389a
CH ₃	C ₆ H ₅	<i>p</i> -(<i>p</i> -CH ₃ CONHC ₆ H ₄ CH=CH)C ₆ H ₄	12	389a
CH ₃	C ₆ H ₅	<i>p</i> -(C ₆ H ₅ N=N)C ₆ H ₄	28	389c
CH ₃	<i>o</i> -O ₂ NC ₆ H ₄	C ₆ H ₅	Small	144
CH ₃	<i>p</i> -O ₂ NC ₆ H ₄	C ₆ H ₅	—	144
CH ₃	<i>p</i> -O ₂ NC ₆ H ₄	<i>o</i> -O ₂ NC ₆ H ₄	—	144
CH ₃	<i>p</i> -O ₂ NC ₆ H ₄	<i>m</i> -O ₂ NC ₆ H ₄	—	144
CH ₃	<i>p</i> -O ₂ NC ₆ H ₄	<i>p</i> -O ₂ NC ₆ H ₄	—	144
CH ₃	<i>p</i> -O ₂ NC ₆ H ₄	2,4-(O ₂ N) ₂ C ₆ H ₃	48	129, 144
CH ₃	2,4-(O ₂ N) ₂ C ₆ H ₃	C ₆ H ₅	—	390
CH ₃	2,4-(O ₂ N) ₂ C ₆ H ₃	<i>o</i> -O ₂ NC ₆ H ₄	—	391
CH ₃	2,4-(O ₂ N) ₂ C ₆ H ₃	<i>m</i> -O ₂ NC ₆ H ₄	—	390
CH ₃	2,4-(O ₂ N) ₂ C ₆ H ₃	<i>p</i> -O ₂ NC ₆ H ₄	—	390

CH_3	$2,4\text{-(O}_2\text{N)}_2\text{C}_6\text{H}_3$	$p\text{-O}_2\text{NC}_6\text{H}_4$	390
CH_5	$(\text{C}_6\text{H}_5)_2\text{NCO}$	C_6H_5	398 <i>d</i>
$(\text{CH}_3)_2\text{C}$	C_6H_5	C_6H_5	143
$(\text{CH}_3)_3\text{C}$	C_6H_5	$p\text{-O}_2\text{NC}_6\text{H}_4$	143
$(\text{CH}_3)_4\text{C}$	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3^*$	C_6H_5	143
$(\text{CH}_3)_5\text{C}$	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3^*$	$p\text{-BrC}_6\text{H}_4$	143
$(\text{CH}_3)_6\text{C}$	$2,4\text{-(CH}_3)_2\text{C}_6\text{H}_3^*$	$p\text{-O}_2\text{NC}_6\text{H}_4$	143
$\text{C}_2\text{H}_5\text{O}_2\text{C}$	C_6H_5	C_6H_5	148
$\text{C}_2\text{H}_5\text{O}_2\text{C}$	$p\text{-HO}_3\text{SC}_6\text{H}_4^{\dagger}$	C_6H_5	401
C_2H_5	C_6H_5	C_6H_5	393, 392
CH_3CO	C_6H_5	C_6H_5	52, 226
CH_3CO	C_6H_5	C_6H_5	52
CH_3CO	C_6H_5	$p\text{-CH}_3\text{C}_6\text{H}_4$	52
CH_3CO	C_6H_5	$p\text{-O}_2\text{NC}_6\text{H}_4$	389
$n\text{-C}_4\text{H}_9$	C_6H_5	$p\text{-HO}_3\text{SC}_6\text{H}_4$	392
$n\text{-C}_3\text{H}_7$	Cholyl ($\text{C}_{24}\text{H}_{39}\text{O}_5$)	C_6H_5	387
$i\text{-C}_3\text{H}_7$	C_6H_5	C_6H_5	393 <i>a</i>
$\text{CH}_3\text{CH}_2\text{C(CH}_3)_2$	C_6H_5	C_6H_5	392
$(\text{CH}_3)_2\text{CHCH}_2$	C_6H_5	C_6H_5	392
$n\text{-C}_6\text{H}_{13}$	C_6H_5	C_6H_5	392
$n\text{-C}_8\text{H}_{17}$	C_6H_5	C_6H_5	148
$n\text{-C}_{10}\text{H}_{21}$	C_6H_5	$p\text{-HO}_3\text{SC}_6\text{H}_4$	389
Cyclohexyl	$\text{H}_2\text{N(CH}_2)_6\text{N(CH}_2)_6\text{C}$	5-Tetrazolyl	19 <i>d</i>
$n\text{-C}_7\text{H}_{15}$	C_6H_5	C_6H_5	393, 392
$n\text{-C}_9\text{H}_{19}$	C_6H_5	$4\text{-HO}_3\text{SC}_6\text{H}_4$	389
$n\text{-C}_{11}\text{H}_{23}$	C_6H_5	C_6H_5	392
$n\text{-C}_{13}\text{H}_{27}$	C_6H_5	C_6H_5	392
$n\text{-C}_{15}\text{H}_{31}$	C_6H_5	C_6H_5	148

Quant.

Note: References 177-480 are on pp. 136-142.

* Only the *syn* isomer of methyl glyoxalate 2,4-dimethylphenylhydrazine gave a formazan. The *anti* isomer reacted with the elimination of nitrogen.

† The phenylsulfamyl group was replaced by a phenyl group in the coupling reaction.

TABLE IX—Continued
A. Simple Hydrazones—Continued

R	R'	R''	Yield, %	References
C_6H_5	C_6H_5	$p\text{-BrC}_6\text{H}_4$	82	148
$m\text{-C}_{11}\text{H}_{23}$	C_6H_5	$p\text{-O}_2\text{NC}_6\text{H}_4$	83	148
$m\text{-C}_{10}\text{H}_{18}$	C_6H_5	$p\text{-HO}_3\text{SC}_6\text{H}_4$	Quant.	389
$m\text{-C}_{11}\text{H}_{23}$	C_6H_5	$\alpha\text{-C}_{10}\text{H}_7$	67	148
$m\text{-C}_{10}\text{H}_{18}$	$p\text{-BrC}_6\text{H}_4$	C_6H_5	63	148
$m\text{-C}_{11}\text{H}_{23}$	$p\text{-O}_2\text{NC}_6\text{H}_4$	C_6H_5	60	148
C_6H_5	C_6H_5	C_6H_5	50	394, 18, 19, 19a, 19b, 70 395
C_6H_5	C_6H_5	$p\text{-CH}_3\text{C}_6\text{H}_4$	—	19
C_6H_5	C_6H_5	$p\text{-}i\text{-C}_3\text{H}_7\text{C}_6\text{H}_4$	—	395a
C_6H_5	C_6H_5	$p\text{-}n\text{-C}_{12}\text{H}_{25}\text{C}_6\text{H}_4$	83	395a
C_6H_5	C_6H_5	$p\text{-ClC}_6\text{H}_4$	60	395a, 393
C_6H_5	C_6H_5	$p\text{-BrC}_6\text{H}_4$	50	18, 149
C_6H_5	C_6H_5	$p\text{-IC}_6\text{H}_4$	45–60	396
C_6H_5	C_6H_5	$o\text{-HOC}_6\text{H}_4$	80	303
C_6H_5	C_6H_5	$o\text{-O}_2\text{NC}_6\text{H}_4$	58	19b
C_6H_5	C_6H_5	$p\text{-O}_2\text{NC}_6\text{H}_4$	92	395a, 18
C_6H_5	C_6H_5	$p\text{-CH}_3\text{CONHC}_6\text{H}_4$	55	397
C_6H_5	C_6H_5	$o\text{-HO}_2\text{CC}_6\text{H}_4$	75	303
C_6H_5	C_6H_5	$p\text{-HO}_3\text{SC}_6\text{H}_4$	—	147
C_6H_5	C_6H_5	$p\text{-C}_6\text{H}_5\text{C}_6\text{H}_4$	44	395a, 398
C_6H_5	C_6H_5	$4\text{-CH}_3\text{CONH-2-ClC}_6\text{H}_3$	76	395a
C_6H_5	C_6H_5	$4\text{-CH}_3\text{CONH-3-ClC}_6\text{H}_4$	44	395a
C_6H_5	C_6H_5	$4\text{-CH}_3\text{CONH-2-O}_2\text{NC}_6\text{H}_3$	57	395a
C_6H_5	C_6H_5	$4\text{-CH}_3\text{CONH-2-CH}_3\text{CO}_2\text{C}_6\text{H}_3$	39	395a
C_6H_5	C_6H_5	$p\text{-}n\text{-C}_{12}\text{H}_{25}\text{CONHC}_6\text{H}_4$	—	395a

C_6H_5	$p\text{-CH}_3\text{CONH}(\text{CH}_2)_{12}\text{N}(\text{COC}_6\text{H}_5)_2\text{C}_6\text{H}_4$	—	395 <i>a</i>
C_6H_5	$p\text{-}[(C_6H_5)_2N(\text{CH}_2)_2O_2C]C_6H_4$	64	395 <i>a</i>
C_6H_5	$p\text{-}[(C_6H_5)_2N(\text{CH}_2)_3\text{CH}(\text{C}_6\text{H}_5)\text{NHOSi}(\text{C}_6\text{H}_5)_3]$	47	395 <i>a</i>
C_6H_5	$p\text{-}(C_6H_5)_2\text{CH}-\text{CH}(\text{C}_6H_5)$	74	389 <i>a</i>
C_6H_5	$p\text{-}(p\text{-HOC}_6\text{H}_4)_2\text{CH}-\text{CH}(\text{C}_6H_5)$	32	389 <i>a</i>
C_6H_5	$p\text{-}(p\text{-BrC}_6\text{H}_4)_2\text{CH}-\text{CH}(\text{C}_6H_5)$	33	389 <i>a</i>
C_6H_5	$p\text{-}(p\text{-O}_2\text{NC}_6\text{H}_4)_2\text{CH}-\text{CH}(\text{C}_6H_5)$	33	389 <i>a</i>
C_6H_5	$p\text{-}(p\text{-CH}_3\text{CONHC}_6\text{H}_4)_2\text{CH}-\text{CH}(\text{C}_6H_5)$	14	389 <i>a</i>
C_6H_5	$p\text{-}(C_6H_5)_2N-\text{N}(\text{C}_6H_5)$	50	389 <i>e</i>
C_6H_5	$p\text{-}(p\text{-CH}_3\text{C}_6\text{H}_4\text{N}=\text{N}(\text{C}_6H_5))_2$	53	389 <i>e</i>
C_6H_5	$p\text{-}(p\text{-ClC}_6\text{H}_4\text{N}=\text{N}(\text{C}_6H_5))_2$	12	389 <i>e</i>
C_6H_5	$p\text{-}(p\text{-HOC}_6\text{H}_4\text{N}=\text{N}(\text{C}_6H_5))_2$	28	389 <i>e</i>
C_6H_5	$p\text{-}(p\text{-O}_2\text{NC}_6\text{H}_4\text{N}=\text{N}(\text{C}_6H_5))_2$	57	389 <i>e</i>
C_6H_5	$p\text{-}p\text{-}(\text{CH}_3)_2\text{NC}_6\text{H}_4\text{N}=\text{N}(\text{C}_6H_5)$	23	389 <i>e</i>
C_6H_5	$p\text{-}(p\text{-CH}_3\text{CONHC}_6\text{H}_4\text{N}=\text{N}(\text{C}_6H_5))_2$	35	389 <i>e</i>
C_6H_5	$p\text{-}(2\text{-Cl-4-HOC}_6\text{H}_3\text{N}=\text{N}(\text{C}_6H_5))_2$	27	389 <i>e</i>
C_6H_5	$p\text{-}(3\text{-Cl-4-HOC}_6\text{H}_3\text{N}=\text{N}(\text{C}_6H_5))_2$	8	389 <i>e</i>
C_6H_5	$2,5\text{-(CH}_3)_2\text{-4-(C}_6\text{H}_5\text{N}=\text{N}(\text{C}_6H_5))_2$	50	389 <i>e</i>
C_6H_5	$\alpha\text{-C}_{10}\text{H}_7$	80	150, 147, 149, 390
C_6H_5	$p\text{-C}_{10}\text{H}_7$	47	150, 149, 390
C_6H_5	$4\text{-(C}_6\text{H}_5\text{N}=\text{N)-1-C}_{10}\text{H}_6$	9	389 <i>e</i>
C_6H_5	3-Pyridyl	53	395 <i>a</i>
C_6H_5	6-Quinolyl	—	398 <i>a</i>
C_6H_5	7-Quinolyl	—	398 <i>a</i>
C_6H_5	6-Ethoxy-2-quinolyl	—	398 <i>a</i>
C_6H_5	6-Methoxy-8-quinolyl	20	395 <i>a</i>
C_6H_5	2-Quinolylmethyl	—	398 <i>a</i>
C_6H_5	2-Thiazolyl	—	398 <i>a</i>
C_6H_5	5-Methyl-2-thiazolyl	68	398 <i>b</i>

Note: References 177-480 are on pp. 136-142.

TABLE IX—Continued

1. Simple Hydrazones—Continued

R	R'	R''	Yield, %	References
C_6H_5	C_6H_5	4-Methyl-2-thiazolyl	1-3	398b
C_6H_5	C_6H_5	4,5-Dimethyl-2-thiazolyl	69	398b
C_6H_5	C_6H_5	2,5-Dimethyl-4-(2-thiazolylazo)phenyl	25	389c
C_6H_5	C_6H_5	<i>p</i> -(6-Methyl-2-benzothiazolyl)phenyl	—	398a
C_6H_5	o - $C_6H_4C_6H_5$	C_6H_5	85	19b
C_6H_5	o - $CH_3C_6H_4$	p - $O_2NC_6H_4$	37	19b
C_6H_5	p - $C_6H_4C_6H_5$	C_6H_5	—	19
C_6H_5	p - $CH_3C_6H_4$	p - $CH_3C_6H_4$	—	19
C_6H_5	p - $C_6H_4C_6H_5$	α - $C_{10}H_7$	—	390
C_6H_5	p - $CH_3C_6H_4$	β - $C_{10}H_7$	—	390
C_6H_5	o - $CH_3OC_6H_4$	o - $CH_3OC_6H_4$	—	290a
C_6H_5	p - $CH_3OC_6H_4$	p - $CH_3OC_6H_4$	60	290a
C_6H_5	o - $C_2H_5OC_6H_4$	C_6H_5	91	19b
C_6H_5	o - $C_2H_5OC_6H_4$	p - $O_2NC_6H_4$	51	19b
C_6H_5	p - $C_2H_5OC_6H_4$	C_6H_5	74	19b
C_6H_5	p - $C_2H_5OC_6H_4$	C_6H_5	26	19b
C_6H_5	o - ClC_6H_4	C_6H_5	55	19b
C_6H_5	p - ClC_6H_4	C_6H_5	50	19b
C_6H_5	p - ClC_6H_4	p - ClC_6H_4	18	19b
C_6H_5	p - ClC_6H_4	p -($C_6H_5N=N$) C_6H_4	50	18, 149
C_6H_5	p - BrC_6H_4	C_6H_5	42-51	396
C_6H_5	p - IC_6H_4	p - IC_6H_4	10	19b
C_6H_5	o - $C_2NC_6H_4$	C_6H_5	16	19b
C_6H_5	p - $O_2NC_6H_4$	C_6H_5	36-58	396
C_6H_5	p - $O_2NC_6H_4$	p - IC_6H_4	8	323b
C_6H_5	p - $O_2NC_6H_4$	p - $O_2NC_6H_4$	22	398c
C_6H_5	p - $O_2NC_6H_4$	p - $C_6H_5C_6H_4$	41	150, 390
C_6H_5	p - $O_2NC_6H_4$	α - $C_{10}H_7$	—	—

C_3H_7	$\beta-C_{10}H_7$	—	390
C_4H_8	$p-O_2NC_6H_4$	52	398e
C_4H_7	$p-O_2NC_6H_3$	52	398e
C_4H_6	$\mu-O_2NC_6H_4$	21	398e
C_4H_5	$p-O_2NC_6H_3$	5	398e
C_5H_6	$\mu-O_2NC_6H_4$	75-80	303
C_5H_5	$o-HO_2CC_6H_4$	—	141
C_5H_4	$m-HO_2CC_6H_4$	—	141
C_5H_3	$m-HO_2CC_6H_3$	—	141
C_5H_2	$m-HO_2CC_6H_2$	—	141
C_5H	$m-HO_2CC_6H$	—	141
C_6H_5	$p-HO_2CC_6H_4$	—	141
C_6H_4	$p-(C_6H_5N=N)C_6H_4$	10	389e
C_6H_3	$p-(C_6H_5N=N)C_6H_3$	26	389e
C_6H_2	C_6H_5	37	147
C_6H	C_6H_5	—	19b
C_6H_5	C_6H_5	—	398d
C_6H_4	C_6H_5	—	147, 149, 390
C_6H_3	C_6H_5	—	390
C_6H_2	C_6H_5	—	390
C_6H	$p-CH_3C_6H_4$	39§	150, 149
C_6H_5	$p-O_2NC_6H_4$	—	398d
C_6H_4	C_6H_5	—	398d
C_6H_3	$p-C_6H_5C_6H_4$	13	398
C_6H_2	C_6H_5	—	387
C_6H	$p-(C_6H_5CH=CH)C_6H_4$	47	389a
C_6H_5	$p-ClC_6H_5$	—	398a
C_6H_4	C_6H_5	—	19d

Note: References 177-480 are on pp. 136-142.

† These products are probably 4-arylazonaaphthylhydrazones rather than formazans. See ref. 150.

‡ A 45% yield of the 1-phenylazo-2-naphthylhydrazone of benzaldehyde was obtained also.

TABLE IX—Continued
 A. Simple Hydrazones—Continued

R	R'	R''	Yield, %	References
C_6H_5	2-Quinolyl	$p\text{-ClC}_6H_5$	—	398a
C_6H_5	2-Thiazolyl	C_6H_5	66	398b
C_6H_5	4-Methyl-2-thiazolyl	C_6H_5	50	398b
C_6H_5	4-Phenyl-2-thiazolyl	C_6H_5	38	398b
C_6H_5	4,5-Diphenyl-2-thiazolyl	C_6H_5	22	398b
C_6H_5	$H_2N(NH=)C$	C_6H_5	61	402
C_6H_5	$H_2N(HN=)C$	$m\text{-O}_2\text{NC}_6H_4$	—	402
$p\text{-CH}_3\text{C}_6H_4$	$H_2N(HN=)C$	5-Tetrazolyl	—	19d
$p\text{-CH}_3\text{OC}_6H_4$	C_6H_5	C_6H_5	—	15
$p\text{-CH}_3\text{OC}_6H_4$	C_6H_5	$p\text{-(C}_6H_5\text{CH=CH)C}_6H_4$	83	389a
$p\text{-CH}_3\text{OC}_6H_4$	$p\text{-ClC}_6H_4$	$p\text{-ClC}_6H_4$	43	323b
$p\text{-CH}_3\text{OC}_6H_4$	$p\text{-O}_2\text{NC}_6H_4$	$p\text{-O}_2\text{NC}_6H_4$	15	323b
$p\text{-CH}_3\text{OC}_6H_4$	2-Pyridyl	$p\text{-ClC}_6H_4$	—	398a
$p\text{-CH}_3\text{OC}_6H_4$	2-Quinolyl	$p\text{-ClC}_6H_4$	—	398a
$p\text{-CH}_3\text{OC}_6H_4$	$H_2N(NH=)C$	5-Tetrazolyl	—	19d
$p\text{-CH}_3\text{OC}_6H_4$	2-Pyridyl	5-Tetrazolyl	—	398a
$p\text{-CH}_3\text{OC}_6H_4$	2-Quinolyl	5-Tetrazolyl	—	398a
$p\text{-CH}_3\text{OC}_6H_4$	$o\text{-CH}_3\text{OC}_6H_4$	$o\text{-CH}_3\text{OC}_6H_4$	44	323b
$p\text{-CH}_3\text{OC}_6H_4$	$H_2N(NH=)C$	5-Tetrazolyl	—	19d
$p\text{-BrC}_6H_4$	C_6H_5	$p\text{-BrC}_6H_4$	80	395a
$p\text{-BrC}_6H_4$	C_6H_5	2,4,6- Br_3C_6H_2	10	395a
$p\text{-BrC}_6H_4$	C_6H_5	$p\text{-(C}_6H_5\text{CH=CH)C}_6H_4$	47	389a
$o\text{-HOC}_6H_4$	$(C_6H_5)_2\text{NCO}$	C_6H_5	—	398d
$o\text{-HOC}_6H_4$	2-Pyridyl	$p\text{-ClC}_6H_4$	—	398a
$o\text{-HOC}_6H_4$	2-Quinolyl	$p\text{-ClC}_6H_4$	—	398a
$p\text{-HOC}_6H_4$	C_6H_5	$p\text{-(C}_6H_5\text{N=N)C}_6H_4$	50	389c

$p\text{-NCC}_6\text{H}_4$	C_6H_5	65	395 <i>a</i>
$p\text{-NCC}_6\text{H}_4$	$p\text{-NCC}_6\text{H}_4$	80	395 <i>a</i>
$o\text{-O}_2\text{NC}_6\text{H}_4$	$p\text{-ClC}_6\text{H}_4$	—	398 <i>a</i>
$o\text{-O}_2\text{NC}_6\text{H}_4$	$p\text{-ClC}_6\text{H}_4$	—	398 <i>a</i>
$p\text{-O}_2\text{NC}_6\text{H}_4$	C_6H_5	40	19 <i>b</i> , 395 <i>a</i>
$p\text{-O}_2\text{NC}_6\text{H}_4$	$p\text{-CH}_3\text{OC}_6\text{H}_4$	51	323 <i>b</i>
$p\text{-O}_2\text{NC}_6\text{H}_4$	$p\text{-C}_6\text{H}_4\text{C}_6\text{H}_4$	49	398 <i>c</i>
$p\text{-O}_2\text{NC}_6\text{H}_4$	$3\text{-CH}_3\text{O-4-(}m\text{-CH}_3\text{OC}_6\text{H}_4)_2\text{C}_6\text{H}_3$	23	398 <i>c</i>
$p\text{-O}_2\text{NC}_6\text{H}_4$	C_6H_5	—	402
$p\text{-O}_2\text{NC}_6\text{H}_4$	$p\text{-(C}_6\text{H}_5\text{CH=CH)C}_6\text{H}_4$	33	389 <i>a</i>
$p\text{-HO}_2\text{CC}_6\text{H}_4$	$p\text{-(C}_6\text{H}_5\text{CH=CH)C}_6\text{H}_4$	40	389 <i>a</i>
$p\text{-CH}_3\text{CONHC}_6\text{H}_4$	C_6H_5	53	395 <i>a</i>
$p\text{-CH}_3\text{CONHC}_6\text{H}_4$	$p\text{-CH}_3\text{CONHC}_6\text{H}_4$	17	395 <i>a</i>
$p\text{-CH}_3\text{CONHC}_6\text{H}_4$	$p\text{-(}p\text{-HOC}_6\text{H}_4\text{N=N)C}_6\text{H}_4$	—	389 <i>c</i>
$m\text{-HO}_2\text{SC}_6\text{H}_4$	C_6H_5	—	147
$3,4\text{-(CH}_2\text{O)}_2\text{C}_6\text{H}_4$	$p\text{-CH}_3\text{OC}_6\text{H}_4$	25	395 <i>a</i>
$\text{C}_6\text{H}_4\text{CH}_2$	C_6H_5	—	387
$\text{C}_6\text{H}_4\text{CO}$	C_6H_5	—	70, 204
$p\text{-C}_6\text{H}_4\text{C}_6\text{H}_4$	C_6H_5	43	398
$p\text{-C}_6\text{H}_4\text{C}_6\text{H}_4$	$p\text{-C}_6\text{H}_5\text{C}_6\text{H}_4$	23	398
2-Furyl	C_6H_5	14	402 <i>a</i>
2-Furyl	C_6H_5	—	398 <i>d</i>
2-Furyl	$p\text{-ClC}_6\text{H}_4$	—	398 <i>a</i>
2-Furyl	$p\text{-ClC}_6\text{H}_4$	—	398 <i>a</i>
2-Furyl	C_6H_5	—	387
2-Furyl	$m\text{-F}_3\text{CC}_6\text{H}_4$	—	398 <i>a</i>
2-Thienyl	C_6H_5	46	402 <i>a</i>
2-Pyridyl	$p\text{-CH}_3\text{OC}_6\text{H}_4$	95	402 <i>a</i>
2-Pyridyl	$p\text{-ClC}_6\text{H}_4$	40	402 <i>a</i>
2-Pyridyl	$o\text{-H}_2\text{NC}_6\text{H}_4$	35	402 <i>b</i>

Note: References 177-480 are on pp. 136-142.

TABLE IX—Continued
A. Simple Hydrazones—Continued

R	R'	R''	Yield, %	References
2-Pyridyl	C ₆ H ₅	<i>p</i> -(C ₆ H ₅ CH=CH)C ₆ H ₄	40	402 <i>a</i>
2-Pyridyl	C ₆ H ₅	<i>p</i> -(C ₆ H ₅ N=N)C ₆ H ₄	39	402 <i>a</i>
2-Pyridyl	2-Pyridyl	<i>p</i> -ClC ₆ H ₄	—	398 <i>a</i>
2-Pyridyl	2-Quinolyl	<i>p</i> -ClC ₆ H ₄	—	398 <i>a</i>
2-Pyridyl	2-Quinolyl	6-Quinolyl	—	398 <i>a</i>
4-Pyridyl	2-Quinolyl	<i>p</i> -ClC ₆ H ₄	—	398 <i>a</i>
4-Pyridyl	2-Quinolyl	6-Quinolyl	—	398 <i>a</i>
2-Thienyl-1,2,3-triazol-4-yl	C ₆ H ₅	C ₆ H ₅	59	402 <i>a</i>
2,6-Dioxo-4-pyrimidyl	C ₆ H ₅	C ₆ H ₅	76	399
2-Quinolyl	C ₆ H ₅	C ₆ H ₅	50	402 <i>d</i> , 139 <i>a</i>
2-Quinolyl	C ₆ H ₅	<i>o</i> -HO ₂ CC ₆ H ₄	65	400, 402 <i>e</i>
2-Benzothiazolyl	C ₆ H ₅	C ₆ H ₅	47	402 <i>d</i> , 402 <i>f</i> , 402 <i>g</i>
2-Benzothiazolyl	C ₆ H ₅	<i>p</i> -ClC ₆ H ₄	—	132 <i>b</i> , 402 <i>f</i>
2-Benzothiazolyl	C ₆ H ₅	<i>p</i> -O ₂ N ₂ C ₆ H ₄	—	132 <i>b</i> , 402 <i>f</i> , 402 <i>h</i>
2-Benzothiazolyl	C ₆ H ₅	<i>o</i> -HO ₂ CC ₆ H ₄	56	402 <i>d</i>
2-Benzothiazolyl	<i>p</i> -ClC ₆ H ₄	C ₆ H ₅	—	132 <i>b</i> , 402 <i>f</i>
2-Benzothiazolyl	<i>p</i> -ClC ₆ H ₄	<i>p</i> -ClC ₆ H ₄	—	132 <i>b</i> , 402 <i>f</i>
2-Benzothiazolyl	<i>p</i> -O ₂ N ₂ C ₆ H ₄	C ₆ H ₅	—	132 <i>b</i> , 402 <i>f</i> , 402 <i>h</i>
2-Benzothiazolyl	<i>p</i> -O ₂ N ₂ C ₆ H ₄	<i>p</i> -O ₂ N ₂ C ₆ H ₄	—	132 <i>b</i> , 402 <i>f</i> , 402 <i>h</i>
2-Benzof[<i>f</i>]quinolyl	C ₆ H ₅	C ₆ H ₅	48	402 <i>g</i>
2-Benzof[<i>f</i>]quinolyl	C ₆ H ₅	<i>o</i> -HO ₂ CC ₆ H ₄	65	402 <i>g</i>

B. Hydrazones of Sugars

Hydrazine	Substituent in Aniline	Product (Yield, %)	References
D-Glucose phenylhydrazine	—	D-Glucose diphenylformazan (64)	139 <i>b</i> , 139 <i>c</i>
D-Glucose phenyllosazone	—	D-Glucose phenyllosazone (20)	139 <i>a</i>
Anhydro-D-glucose phenyllosazone	—	Anhydro-D-glucose phenyllosazone formazan (27)	139 <i>d</i>
D-Galactose phenylhydrazine	—	D-Galactose diphenylformazan (73)	139 <i>b</i> , 139 <i>c</i> , 139 <i>e</i>
D-Galactose phenylhydrazine	4-Bromo	D-Galactose phenyl-(<i>p</i> -bromophenyl)formazan	139 <i>f</i>
D-Galactose <i>p</i> -bromophenylhydrazine	—	D-Galactose phenyl-(<i>p</i> -bromophenyl)formazan	139 <i>f</i>
D-Mannose phenylhydrazine	—	D-Mannose diphenylformazan (68)	139 <i>b</i> , 139 <i>c</i>
L-Arabinose phenylhydrazine	—	L-Arabinose diphenylformazan (51)	139 <i>b</i>
L-Rhamnose phenylhydrazine	—	L-Rhamnose diphenylformazan (45)	139 <i>b</i> , 139 <i>e</i>
D-Xylose phenylhydrazine	—	D-Xylose diphenylformazan (55)	139 <i>b</i>
D-Mannose pentaacetate phenylhydrazine	—	D-Mannose diphenylformazan pentaacetate (57)	139 <i>e</i>

Note: References 177-480 are on pp. 136-142.

TABLE IX—Continued
C. Diformazans from Hydrazones and Diamines

R	R'	Y	Yield, %	References
C ₆ H ₃	C ₆ H ₅	H	—	179
C ₆ H ₅	C ₆ H ₅	H	90	402j
C ₆ H ₅	C ₆ H ₅	CH ₃	39	402j
C ₆ H ₅	C ₆ H ₅	CH ₃ O	72	402k, 402j
C ₆ H ₅	C ₆ H ₅	H	11	398c
<i>p</i> -O ₂ NC ₆ H ₄	<i>p</i> -O ₂ NC ₆ H ₄	CH ₃ O	18	398c
<i>p</i> -O ₂ NC ₆ H ₄	<i>p</i> -O ₂ NC ₆ H ₄	CH ₃ O	—	398a
2-Pyridyl	2-Pyridyl	CH ₃ O	—	398a
2-Quinolyl	2-Quinolyl	CH ₃ O	—	402k
C ₆ H ₅	C ₆ H ₅	CH ₃ O	—	398a
2-Pyridyl	2-Pyridyl	CH ₃ O	—	398a
2-Quinolyl	2-Quinolyl	CH ₃ O	—	402k
C ₆ H ₅	C ₆ H ₅	CH ₃ O	—	398a
2-Pyridyl	2-Pyridyl	CH ₃ O	—	398a
2-Quinolyl	2-Quinolyl	CH ₃ O	—	398a
<i>p</i> -O ₂ NC ₆ H ₄	<i>p</i> -O ₂ NC ₆ H ₄	H	49	398c
<i>p</i> -O ₂ NC ₆ H ₄	<i>p</i> -O ₂ NC ₆ H ₄	CH ₃ O	12	398c
C ₆ H ₅	C ₆ H ₅	CH ₃ O	79	402k
C ₆ H ₅	C ₆ H ₅	CH ₃ O	70	402k, 398a
2-Pyridyl	2-Pyridyl	CH ₃ O	—	398a
2-Quinolyl	2-Quinolyl	CH ₃ O	—	398a

2-Pyridyl	C ₆ H ₅	CH ₃ O	—	398a
2-Pyridyl	2-Pyridyl	CH ₃ O	—	398a
4-Pyridyl	C ₆ H ₅	CH ₃ O	49	402k, 398a
4-Pyridyl	2-Pyridyl	CH ₃ O	—	398a
2-Phenyl	C ₆ H ₅	H	—	398a
2-Ethyl	C ₆ H ₅	CH ₃ O	61	402k, 398a
2-Phenaphthyl	C ₆ H ₅	CH ₃ O	64	402k, 398a
2-Phenaphthyl	2-Pyridyl	CH ₃ O	—	398a
2-Benzothiazyl	C ₆ H ₅	CH ₃ O	—	398a

D. Diformazans from Dihydrazones

Hydrazone	Substituent in Aniline	Product (Yield, %)	References
Glyoxal diethylhydrazone	—	Bis-(N'-Cholyl-N'-phenylformazan)	387
Dioxosuccinic acid phenylhydrazone	—	Bis-(N,N'-Diphenylformazan) (small)	153, 180
Succinaldehyde bisphenylhydrazone	—	C,C'-Ethylenebis-(N,N'-diphenylformazan) (53)	179
Succinaldehyde bisphenylhydrazone	4-Phenylazo	(C,C'-Ethylenebis-[N-phenyl-N'-(p-phenylazophenyl)-formazan] (29)	389c
Succinaldehyde bisphenylhydrazone	—	(C,C'-Hexamethylenebis-(N,N'-diphenylformazan)	395a
	4-Phenylazo	(C,C'-Hexamethylenebis-[N-phenyl-N'-(p-phenylazo-phenyl)formazan] (39)	389c
Terephthaldehyde bisphenylhydrazone	—	p-Phenylenebis-(N,N'-diphenylformazan) (90)	179
	4-Carboxy	p-Phenylenebis-[N-phenyl-N'-(p-carboethoxyphenyl)-formazan] (47)	179

Note: References 177-480 are on pp. 136-142.

The starting material was phenylglyoxylic acid phenylhydrazone.

The product was also obtained from phenylglyoxylic acid phenylhydrazone in 50% yield.

TABLE IX—Continued
E. *Diformazans from Dibenzalaminoguanidines*



R	R'	References
C ₆ H ₅	C ₆ H ₅	403
C ₆ H ₅	<i>o</i> -O ₂ NC ₆ H ₄	19 <i>d</i>
C ₆ H ₅	<i>p</i> -O ₂ NC ₆ H ₄	19 <i>d</i>
C ₆ H ₅	<i>p</i> -HO ₃ SC ₆ H ₄	403
C ₆ H ₅	4-CH ₃ -2-(O ₂ N)C ₆ H ₃	19 <i>d</i>
C ₆ H ₅	2-CH ₃ -6-(O ₂ N)C ₆ H ₃	19 <i>d</i>
C ₆ H ₅	2-CH ₃ -4-ClC ₆ H ₃	19 <i>d</i>
C ₆ H ₅	β-C ₁₀ H ₇	19 <i>d</i>
C ₆ H ₅	4-Antipyril	19 <i>d</i>
<i>m</i> -O ₂ NC ₆ H ₄	C ₆ H ₅	403

F. *Hydrazones Which Couple with Elimination of a Substituent*



R	R'	R''	R'''	Yield, %	References
H	HO ₂ C	C ₆ H ₅	C ₆ H ₅	20	143
H	HO ₂ C	C ₆ H ₅	2,4-Br ₂ C ₆ H ₃	—	170 <i>a</i>
Cl	HO ₂ C	<i>o</i> -ClC ₆ H ₄	<i>p</i> -O ₂ NC ₆ H ₄	Quant.	145

Cl	HO ₂ C	<i>o</i> -CH ₃ O ₂ CCH ₃	<i>p</i> -O ₂ NC ₆ H ₄	—	145
Cl	HO ₂ C	2,4-(CH ₃) ₂ C ₆ H ₃	<i>p</i> -O ₂ NC ₆ H ₄	—	145
CH ₃	HO ₂ C	C ₆ H ₅	C ₆ H ₅	87-89	27, 153, 95 <i>a</i>
CH ₃	HO ₂ C	C ₆ H ₅	<i>o</i> -O ₂ NC ₆ H ₄	—	144
CH ₃	HO ₂ C	<i>o</i> -CH ₃ OC ₆ H ₄	<i>o</i> -CH ₃ OC ₆ H ₄	70	290 <i>a</i>
CH ₃	HO ₂ C	<i>p</i> -CH ₃ OC ₆ H ₄	<i>p</i> -CH ₃ OC ₆ H ₄	—	290 <i>a</i>
CH ₃ O ₂ C	HO ₂ C	C ₆ H ₅	C ₆ H ₅	—	70
C ₂ H ₅ O ₂ C	HO ₂ C	C ₆ H ₅	C ₆ H ₅	Quant.	70
C ₂ H ₅ O ₂ C	HO ₂ C	C ₆ H ₅	<i>p</i> -CH ₃ C ₆ H ₄	—	19
CH ₃ CO	HO ₂ C	C ₆ H ₅	C ₆ H ₅	75	52, 142
C ₂ H ₅	HO ₂ C	C ₆ H ₅	C ₆ H ₅	—	19
C ₆ H ₅	HO ₂ C	C ₆ H ₅	<i>o</i> -CH ₃ C ₆ H ₄	—	141
C ₆ H ₅	HO ₂ C	C ₆ H ₅	<i>o</i> -O ₂ NC ₆ H ₄	—	141
C ₄ H ₉	HO ₂ C	C ₆ H ₅	<i>m</i> -O ₂ NC ₆ H ₄	—	141
C ₆ H ₅	HO ₂ C	C ₆ H ₅	<i>p</i> -O ₂ NC ₆ H ₄	—	141
C ₆ H ₅	HO ₂ C	C ₆ H ₅	2,4-(CH ₃) ₂ C ₆ H ₃	—	141
C ₆ H ₅ CO	HO ₂ C	C ₆ H ₅	C ₆ H ₅	—	120
C ₆ H ₅ N=N	HO ₂ C	C ₆ H ₅	C ₆ H ₅	56	60, 70, 140, 151
C ₆ H ₅ N=N	HO ₂ C	C ₆ H ₅	<i>p</i> -CH ₃ C ₆ H ₄	—	19
C ₆ H ₅ N=N	HO ₂ C	<i>p</i> -CH ₃ C ₆ H ₄	C ₆ H ₅	—	19
HOCH ₂ CH ₂ **	HO ₂ C	<i>o</i> -CH ₃ C ₆ H ₄	<i>o</i> -ClC ₆ H ₄	23	403 <i>a</i>
HOCH ₂ CH ₂ **	HO ₂ C	<i>o</i> -ClC ₆ H ₄	<i>o</i> -CH ₃ C ₆ H ₄	7	403 <i>a</i>
HOCH ₂ CH ₂ **	HO ₂ C	<i>o</i> -ClC ₆ H ₄	<i>o</i> -ClC ₆ H ₄	38	403 <i>a</i>
HOCH ₂ CH ₂ **	HO ₂ C	<i>o</i> -O ₂ NC ₆ H ₄	<i>o</i> -O ₂ NC ₆ H ₄	4	403 <i>a</i>

Note: References 177-480 are on pp. 136-142.

** The starting material was the hydrazone of α -oxo- γ -butyrolactone.

TABLE IX—Continued

F. Hydrazones Which Couple with Elimination—Continued

R	R'	R''	R'''	Yield, %	References
$\text{CH}_3\text{CHOHCH}_2\text{H}^\dagger$	HO_2C	C_6H_5	C_6H_5	4	403a
$\text{CH}_3\text{CHOHCH}_2\text{H}^\dagger$	HO_2C	$o\text{-ClC}_6\text{H}_4$	$o\text{-ClC}_6\text{H}_4$	15	403a
$\text{CH}_3\text{O}_2\text{C}$	CH_3CO	$p\text{-CH}_3\text{C}_6\text{H}_4$	C_6H_5	—	19
$\text{C}_2\text{H}_5\text{O}_2\text{C}$	CH_3CO	C_6H_5	C_6H_5	—	60, 151
$\text{C}_2\text{H}_5\text{O}_2\text{C}$	CH_3CO	$p\text{-CH}_3\text{C}_6\text{H}_4$	C_6H_5	—	19
<i>l</i> -Carbomethyloxy	CH_3CO	$p\text{-CH}_3\text{C}_6\text{H}_4$	$p\text{-ClC}_6\text{H}_4$	—	146
<i>l</i> -Carbomethyloxy	CH_3CO	$p\text{-BrC}_6\text{H}_4$	$p\text{-CH}_3\text{C}_6\text{H}_4$	—	146
$\text{C}_6\text{H}_5\text{N}=\text{N}$	CH_3CO	C_6H_5	C_6H_5	—	52, 142
$\text{C}_6\text{H}_5\text{N}=\text{N}$	HO_2CCO	C_6H_5	C_6H_5	—	153
$\text{C}_2\text{H}_5\text{O}_2\text{C}$	$\text{C}_2\text{H}_5\text{O}_2\text{CCO}$	$p\text{-BrC}_6\text{H}_4$	$p\text{-BrC}_6\text{H}_4$	—	66
NO_2	HOCH_2	C_6H_5	C_6H_5	—	107
NO_2	$\text{CH}_3\text{CH}(\text{OH})$	C_6H_5	C_6H_5	—	107
NO_2	$\text{Cl}_2\text{CCH}(\text{OH})$	C_6H_5	C_6H_5	—	107
NO_2	$\text{CH}_3\text{CH}_2\text{CH}(\text{OH})$	C_6H_5	C_6H_5	—	107
NO_2	$\text{CH}_3(\text{CH}_2)_2\text{CH}(\text{OH})$	C_6H_5	C_6H_5	—	107
NO_2	$\text{CH}_3(\text{CH}_2)_3\text{CH}(\text{OH})$	C_6H_5	C_6H_5	—	107
NO_2	$\text{C}_6\text{H}_5\text{CH}(\text{OH})$	C_6H_5	C_6H_5	—	107

Note: References 177–480 are on pp. 136–142.

[†] The starting material was the hydrazone of α -oxo- γ -valerolactone.

TABLE X

COUPLING OF DIAZONIUM SALTS WITH HETEROCYCLIC COMPOUNDS

4. 5-Pyrazolones

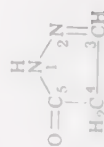
Heterocyclic Compound, Substituent(s) in	Substituent(s) in Aniline*	Product (Yield, %), Substituent(s) in	References
	—	4-Phenylazo (quant.)	405, 404
—	4-Methyl	4-(<i>p</i> -Tolylazo) (quant.)	405, 404, 406, 407
—	—	3-Methyl-4-phenylazo	404, 407, 408
3-Methyl	2-Aminoanthraquinone	3-Methyl-4-(2-anthraquinonylazo) (quant.)	250
—	—	3-Carboxy-4-phenylazo	404
3-Carboxy	2-Carboxy	3-Carboxy-4-(<i>o</i> -carboxyphenylazo)	404
—	2-Carboxy	3-Carboxy-4-(<i>o</i> -carboxyphenylazo)	409
3-Carbomethoxy	—	3-Carbomethoxy-4-phenylazo	404
3-Carboxy	—	3-Carboxy-4-phenylazo	404
2-Carboxy	2-Carboxy	3-Carboxy-4-(<i>o</i> -carboxyphenylazo)	404
4-Methyl	4-Methyl	3-Carboxy-4-(<i>o</i> -carboxyphenylazo)	409
—	—	3-Phenyl-4-phenylazo	65
2-Methyl	2-Methyl	3-Phenyl-4-(<i>o</i> -tolylazo)	404, 407, 408, 409
4-Methyl	4-Methyl	3-Phenyl-4-(<i>p</i> -tolylazo)	404, 409
α -Naphthylamine	α -Naphthylamine	3-Phenyl-4-(α -naphthylazo)	404, 409
β -Naphthylamine	β -Naphthylamine	3-Phenyl-4-(β -naphthylazo)	404, 409

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued
A. 5-Pyrazolones—Continued

Heterocyclic Compound,
Substituent(s) in



3-(2-Furyl)

1-Methyl-3-amino

1-Methyl-3-carboethoxy

1-Methyl-3-phenyl

1-Acetyl-3-phenyl

1-Phenyl

1-Phenyl-3-methyl

Substituent(s)
in Aniline*

—

4-Methoxy

4-Methoxy

—

—

—

—

2-Methyl

3-Methyl

4-Methyl

2-Methoxy

4-Methoxy

2-Ethoxy

4-Ethoxy

2-Chloro

3-Chloro

4-Chloro

1-Bromo

4-Acetyl

2-Nitro

3-Nitro



3-(2-Furyl)-4-phenylazo

1-Methyl-3-amino-4-(*p*-anisylazo) (41)

1-Methyl-3-carboethoxy-4-(*p*-anisylazo) (SS)

1-Methyl-3-phenyl-4-phenylazo

1-Acetyl-3-phenyl-4-phenylazo

1-Phenyl-4-phenylazo

1-Phenyl-3-methyl-4-phenylazo

1-Phenyl-3-methyl-4-(*o*-tolylazo)

1-Phenyl-3-methyl-4-(*m*-tolylazo)

1-Phenyl-3-methyl-4-(*p*-tolylazo)

1-Phenyl-3-methyl-4-(*o*-anisylazo)

1-Phenyl-3-methyl-4-(*p*-anisylazo)

1-Phenyl-3-methyl-4-(*o*-ethoxyphenylazo)

1-Phenyl-3-methyl-4-(*p*-ethoxyphenylazo)

1-Phenyl-3-methyl-4-(*o*-chlorophenylazo)

1-Phenyl-3-methyl-4-(*m*-chlorophenylazo)

1-Phenyl-3-methyl-4-(*p*-chlorophenylazo)

1-Phenyl-3-methyl-4-(*p*-bromophenylazo)

1-Phenyl-3-methyl-4-(*p*-acetylphenylazo)

1-Phenyl-3-methyl-4-(*o*-nitrophenylazo)

1-Phenyl-3-methyl-4-(*m*-nitrophenylazo)

References

410

411

411

412

408

157

413, 414, 415

415, 416, 417

415, 417

415, 417

415, 417

415, 417

415, 417

68, 415

415

415, 417

415, 417

417

415, 417

415, 417

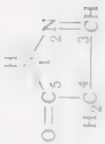
4-Nitro	1-Phenyl-3-methyl-4-(<i>p</i> -nitrophenylazo)	415, 417
4-Acetamido	1-Phenyl-3-methyl-4-(<i>p</i> -acetamidophenylazo)	417
4-Benzamido	1-Phenyl-3-methyl-4-(<i>p</i> -benzamidophenylazo)	417
3-Sulfo	1-Phenyl-3-methyl-4-(<i>m</i> -sulphophenylazo)	418
1-Sulfo	1-Phenyl-3-methyl-4-(<i>p</i> -sulphophenylazo)	418
2,4-Dimethyl	1-Phenyl-3-methyl-4-(2,4-dimethylphenylazo)	417
2,5-Dimethyl	1-Phenyl-3-methyl-4-(2,5-dimethylphenylazo)	417
2,5-Dichloro	1-Phenyl-3-methyl-4-(2,5-dichlorophenylazo)	67, 415
4-Chloro-2-methyl	1-Phenyl-3-methyl-4-(1-chloro-2-methylphenylazo)	415
5-Chloro-2-methyl	1-Phenyl-3-methyl-4-(5-chloro-2-methylphenylazo)	415
1-Chloro-2-nitro	1-Phenyl-3-methyl-4-(4-chloro-2-nitrophenylazo)	415
3-Methyl-4-sulfo	1-Phenyl-3-methyl-4-(3-methyl-4-sulphophenylazo)	418
4-Chloro-3-sulfo	1-Phenyl-3-methyl-4-(4-chloro-3-sulphophenylazo)	418
3-Chloro-5-sulfo	1-Phenyl-3-methyl-4-(3-chloro-5-sulphophenylazo)	419
<i>o</i> -Naphthylamine	1-Phenyl-3-methyl-4-(α -naphthylazo)	415, 417
<i>p</i> -Naphthylamine	1-Phenyl-3-methyl-4-(β -naphthylazo)	415, 417
1-Nitro-2-naphthylamine	1-Phenyl-3-methyl-4-(1-nitro-2-naphthylazo)	417
4-Nitro-1-naphthylamine	1-Phenyl-3-methyl-4-(4-nitro-1-naphthylazo)	417
1-Sulfo-2-naphthylamine	1-Phenyl-3-methyl-4-(1-sulfo-2-naphthylazo)	418
1-(<i>p</i> -Aminophenyl)-piperazine	1-Phenyl-3-methyl-4-(<i>p</i> -1-piperazylphenylazo) (66)	420
6-Amino-2,3-dihydro-3-oxobenzo-1,4-thiazine	1-Phenyl-3-methyl-4-(2,3-dihydro-3-oxobenzo-1,4-thiazin-6-ylazo) (88)	421
Benzidine	4,4'-(4,4'-Biphenylenedisazo)bis-[1-phenyl-3-methyl-5-pyrazolone]	417

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued

A. 5-Pyrazolones—Continued


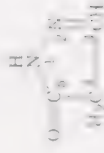
1,3,5-Pyrazolone Compound, Substituent(s) in	Substituent(s) in Aniline*	Product (Yield, %), Substituent(s) in	References
			
1-Phenyl-3-carbethoxymethyl	4-Methyl	1-Phenyl-3-carbethoxymethyl-4-(<i>p</i> -tolylazo) (89)	65
1-Phenyl-3-carbethoxymethyl	4-Nitro	1-Phenyl-3-carbethoxymethyl-4-(<i>p</i> -nitrophenylazo) (85)	65
1,3-Diphenyl		1,3-Diphenyl-4-phenylazo	409, 415, 422
1,3-Diphenyl	2-Methyl	1,3-Diphenyl-4-(<i>o</i> -tolylazo)	409, 415
1,3-Diphenyl	3-Methyl	1,3-Diphenyl-4-(<i>m</i> -tolylazo)	415
1,3-Diphenyl	4-Methyl	1,3-Diphenyl-4-(<i>p</i> -tolylazo)	409, 415
2-Methoxy		1,3-Diphenyl-4-(<i>o</i> -anisylazo)	415
4-Methoxy		1,3-Diphenyl-4-(<i>p</i> -anisylazo)	415
2-Ethoxy		1,3-Diphenyl-4-(<i>o</i> -ethoxyphenylazo)	415
4-Ethoxy		1,3-Diphenyl-4-(<i>p</i> -ethoxyphenylazo)	415
2-Chloro		1,3-Diphenyl-4-(<i>o</i> -chlorophenylazo)	415
3-Chloro		1,3-Diphenyl-4-(<i>m</i> -chlorophenylazo)	415
4-Chloro		1,3-Diphenyl-4-(<i>p</i> -chlorophenylazo)	415
4-Bromo		1,3-Diphenyl-4-(<i>p</i> -bromophenylazo)	415
2-Nitro		1,3-Diphenyl-4-(<i>o</i> -nitrophenylazo)	415
3-Nitro		1,3-Diphenyl-4-(<i>m</i> -nitrophenylazo)	415
4-Nitro		1,3-Diphenyl-4-(<i>p</i> -nitrophenylazo)	415
3-Sulfo		1,3-Diphenyl-4-(<i>m</i> -sulfophenylazo)	418
4-Sulfo		1,3-Diphenyl-4-(<i>p</i> -sulfophenylazo)	418
2,5-Dichloro		1,3-Diphenyl-4-(2,5-dichlorophenylazo)	415
4-Chloro-2-methyl		1,3-Diphenyl-4-(4-chloro-2-methylphenylazo)	415

6-Chloro-2-methyl	1,3-Diphenyl-4-(5-chloro-2-methylphenylazo)	415
4-Chloro-2-nitro	1,3-Diphenyl-4-(4-chloro-2-nitrophenylazo)	415
4-Methyl-4-sulfo	1,3-Diphenyl-4-(3-methyl-4-sulphophenylazo)	418
4-Chloro-3-sulfo	1,3-Diphenyl-4-(4-chloro-3-sulphophenylazo)	418
2-Naphthylamine	1,3-Diphenyl-4-(2-naphthylazo)	409, 415
2-Naphthylamine	1,3-Diphenyl-4-(6-naphthylazo)	409, 415
1-Sulfo-2-naphthylamine	1,3-Diphenyl-4-(1-sulfo-2-naphthylazo)	418
1-Phenyl-3-(2-furyl)-4-phenylazo	1-Phenyl-3-(2-furyl)-4-phenylazo	410, 415
1-Phenyl-3-(2-furyl)-4-(o-tolylazo)	1-Phenyl-3-(2-furyl)-4-(o-tolylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(m-tolylazo)	1-Phenyl-3-(2-furyl)-4-(m-tolylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(p-tolylazo)	1-Phenyl-3-(2-furyl)-4-(p-tolylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(o-anisylazo)	1-Phenyl-3-(2-furyl)-4-(o-anisylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(p-anisylazo)	1-Phenyl-3-(2-furyl)-4-(p-anisylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(o-ethoxyphenylazo)	1-Phenyl-3-(2-furyl)-4-(o-ethoxyphenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(p-ethoxyphenylazo)	1-Phenyl-3-(2-furyl)-4-(p-ethoxyphenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(o-chlorophenylazo)	1-Phenyl-3-(2-furyl)-4-(o-chlorophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(m-chlorophenylazo)	1-Phenyl-3-(2-furyl)-4-(m-chlorophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(p-chlorophenylazo)	1-Phenyl-3-(2-furyl)-4-(p-chlorophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(p-bromophenylazo)	1-Phenyl-3-(2-furyl)-4-(p-bromophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(o-nitrophenylazo)	1-Phenyl-3-(2-furyl)-4-(o-nitrophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(m-nitrophenylazo)	1-Phenyl-3-(2-furyl)-4-(m-nitrophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(p-nitrophenylazo)	1-Phenyl-3-(2-furyl)-4-(p-nitrophenylazo)	410, 415
1-Phenyl-3-(2-furyl)-4-(m-sulphophenylazo)	1-Phenyl-3-(2-furyl)-4-(m-sulphophenylazo)	418
1-Phenyl-3-(2-furyl)-4-(p-sulphophenylazo)	1-Phenyl-3-(2-furyl)-4-(p-sulphophenylazo)	418
1-Phenyl-3-(2-furyl)-4-(2,5-dichlorophenylazo)	1-Phenyl-3-(2-furyl)-4-(2,5-dichlorophenylazo)	415
1-Phenyl-3-(2-furyl)-4-(4-chloro-2-methylphenylazo)	1-Phenyl-3-(2-furyl)-4-(4-chloro-2-methylphenylazo)	415
1-Phenyl-3-(2-furyl)-4-(5-chloro-2-methylphenylazo)	1-Phenyl-3-(2-furyl)-4-(5-chloro-2-methylphenylazo)	415
1-Phenyl-3-(2-furyl)-4-(4-chloro-2-nitrophenylazo)	1-Phenyl-3-(2-furyl)-4-(4-chloro-2-nitrophenylazo)	415

Note: References 177–480 are on pp. 136–142.

THE following is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued

4. 5- <i>pyrazolones</i> —Continued			
Hydroxylic compound. Substituent(s) in	Substituent(s) in Aniline*	Product (Yield, %), Substituent(s) in	References
			
1-Phenyl-3-(2-furyl)-4-(2-furyl)	3-Methyl-4-sulfo-4-chloro-3-sulfo- <i>o</i> -Naphthylamine-β-Naphthylamine-1-Sulfo-2-naphthylamine	1-Phenyl-3-(2-furyl)-4-(3-methyl-4-sulfo-phenylazo) 1-Phenyl-3-(2-furyl)-4-(4-chloro-3-sulfo-phenylazo) 1-Phenyl-3-(2-furyl)-4-β-naphthylazo 1-Phenyl-3-(2-furyl)-4-β-naphthylazo 1-Phenyl-3-(2-furyl)-4-β-naphthylazo	418 418 415 410, 415 418
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-Phenyl-3-(α-phenylbutyramido)-4-(<i>p</i> -anisylazo) (80)	423
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1- <i>p</i> -Tolyl-3-methyl-4-phenylazo	416
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1- <i>p</i> -Tolyl-3-methyl-4-(<i>p</i> -tolylazo)	416
1-Phenyl-3-(2-furyl)-4-(2-furyl)	2,4-Dichloro	1-(<i>o</i> -Chlorophenyl)-3-methyl-4-(<i>o</i> -chlorophenylazo)	424
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Chloro	1-(<i>m</i> -Chlorophenyl)-3-methyl-4-(2,4-dichloro-phenylazo)	424
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Chloro	1-(<i>p</i> -Chlorophenyl)-3-methyl-4-(<i>p</i> -chlorophenylazo)	424
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Chloro	1-(2,4-Dichlorophenyl)-3-methyl-4-phenylazo	424
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-(<i>m</i> -Nitrophenyl)-3-phenyl-4-phenylazo	425
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-(<i>p</i> -Nitrophenyl)-3-methyl-4-(<i>p</i> -anisylazo) (52)	423
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-(<i>p</i> -Nitrophenyl)-3-methyl-4-(<i>o</i> -chlorophenylazo)	68
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-(<i>o</i> -Carboxyphenyl)-3-methyl-4-phenylazo	426
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-(<i>o</i> -Carboxyphenyl)-3-phenyl-4-phenylazo	427
1-Phenyl-3-(2-furyl)-4-(2-furyl)	4-Methoxy	1-(<i>o</i> -Carboxyphenyl)-3-phenyl-4-(<i>p</i> -tolylazo)	427

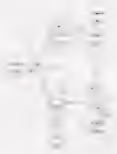
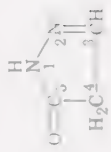
1-(<i>o</i> -Sulfophenyl)-3-methyl-4-phenylazo	428
1-(<i>p</i> -Sulfophenyl)-3-methyl-4-phenylazo	428
1-(<i>o</i> -Sulfophenyl)-3-methyl-4-phenylazo	429
1-(<i>p</i> -Sulfophenyl)-3-methyl-4-phenylazo	430, 431
1-(<i>p</i> -Sulfophenyl)-3-methyl-4-(<i>p</i> -nitrophenylazo)	430, 432
1-(<i>p</i> -Sulfophenyl)-3-methyl-4-(2,5-dichlorophenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-methyl-4-(4-chloro-2-methyl-phenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-methyl-4-(5-chloro-2-methyl-phenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-phenyl-4-phenylazo	430
1-(<i>p</i> -Sulfophenyl)-3-phenyl-4-(<i>o</i> -nitrophenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-phenyl-4-(<i>p</i> -nitrophenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-phenyl-4-(2,5-dichlorophenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-phenyl-4-(4-chloro-2-methyl-phenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-phenyl-4-(5-chloro-2-methyl-phenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-(2-furyl)-4-phenylazo	430
1-(<i>p</i> -Sulfophenyl)-3-(2-furyl)-4-(<i>o</i> -nitrophenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-(2-furyl)-4-(<i>p</i> -nitrophenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-(2-furyl)-4-(2,5-dichloro-phenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-(2-furyl)-4-(4-chloro-2-methyl-phenylazo)	430
1-(<i>p</i> -Sulfophenyl)-3-(2-furyl)-4-(5-chloro-2-methyl-phenylazo)	430

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued

A. 5-Pyrazolones—Continued

Homocyclic Compound, Substituent(s) in	Product (Yield, %), Substituent(s) in	References
		
1-(<i>m</i> -Sulfamylphenyl)-3-methyl-4-(2-hydroxy-4-sulfo-1-naphthyl)amino	1-(<i>m</i> -Sulfamylphenyl)-3-methyl-4-(2-hydroxy-4-sulfo-1-naphthyl)azo	433
2-Hydroxy-4-sulfo-1-naphthylamine	1-(<i>m</i> -Sulfamylphenyl)-3-methyl-4-(2-hydroxy-4-sulfo-1-naphthyl)azo	433
6-nitro-1-naphthylamine	1-(2-Naphthyl)-3-methyl-4-(2-anthraquinonyl)azo	434
4-Methyl-2-Aminoanthraquinone	1-(2-Naphthyl)-3-methyl-4-(2-anthraquinonyl)azo	250
α -Naphthylamine	1-(2-Anthraquinonyl)-3-methyl-4-phenylazo	250
β -Naphthylamine	1-(2-Anthraquinonyl)-3-methyl-4-(α -naphthyl)azo	250
2-Aminoanthraquinone	1-(2-Anthraquinonyl)-3-methyl-4-(2-anthraquinonyl)azo	250
4-Sulfo	1-(2-Benzothiazolyl)-3-methyl-4-phenylazo	435
	1-(2-Benzothiazolyl)-3-methyl-4(<i>p</i> -sulphophenyl)azo	435

13. Miscellaneous Heterocyclic Compounds

Heterocyclic Reagent	Substituent(s) in Aniline*	Product (Yield, %)	Reference
1-Methyl-3-hydroxy-5-pyrazolone imide	4-Methoxy	1-Methyl-3-hydroxy-4-(<i>p</i> -methoxyphenylazo)-5-pyrazolone imide (35)	411
3-(<i>p</i> -Tolyl)-5-pyrazolone imide	—	3-(<i>p</i> -Tolyl)-4-phenylazo-5-pyrazolone imide	318
1-Phenyl-3-methyl-5-pyrazolone imide	—	1-Phenyl-3-methyl-4-phenylazo-5-pyrazolone imide (59)	437, 436
4-Sulfo	—	1-Phenyl-3-methyl-4-(<i>p</i> -sulfiophenylazo)-5-pyrazolone imide	438
β -Naphthylamine	—	1-Phenyl-3-methyl-4-(β -naphthylazo)-5-pyrazolone imide	439
—	—	1-(<i>o</i> -Tolyl)-3-methyl-4-phenylazo-5-pyrazolone imide	440
1-(<i>o</i> -Tolyl)-3-methyl-5-pyrazolone imide	—	1-Phenyl-3-methyl-4-phenylazo-5-thiopyrazolone	441, 442
1-Phenyl-3-methyl-5-thiopyrazolone	—	1-Phenyl-4-phenylazo-5-methyl-3-pyrazolone	443, 444
1-Phenyl-5-methyl-3-pyrazolone	—	1-(<i>o</i> -Tolyl)-4-phenylazo-5-methyl-3-pyrazolone	444
1-(<i>p</i> -Tolyl)-5-methyl-3-pyrazolone	—	1-(<i>p</i> -Tolyl)-4-phenylazo-5-methyl-3-pyrazolone	444
1-(<i>p</i> -Bromophenyl)-5-methyl-3-pyrazolone	—	1-(<i>p</i> -Bromophenyl)-4-phenylazo-5-methyl-3-pyrazolone	445
1-(<i>o</i> -Carboxyphenyl)-5-methyl-3-pyrazolone	—	1-(<i>o</i> -Carboxyphenyl)-4-phenylazo-5-methyl-3-pyrazolone	446
4-Methyl	—	4-(<i>p</i> -Tolylazo)pyrazolidine-3,5-dione	401
—	—	1-Phenyl-4-phenylazopyrazolidine-3,5-dione	447
4-Methyl	—	1-Phenyl-4-(<i>p</i> -tolylazo)pyrazolidine-3,5-dione	448
1-Phenyl-4-ethylpyrazolidine-3,5-dione	—	1-Phenyl-4-ethyl-4-phenylazopyrazolidine-3,5-dione	449

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued

B. Miscellaneous Heterocyclic Compounds—Continued		
Heterocyclic Reactant	Substituent(s) in Aniline*	Product (Yield, %)
1- <i>p</i> -Tolylpyrazolidine-3,5-dione	—	1-(<i>p</i> -Tolyl)-4-phenylazopyrazolidine-3,5-dione
3-Methyl-5-isoxazolone	—	3-Methyl-4-phenylazo-5-isoxazolone (quant.)
	2-Methyl	3-Methyl-4-(<i>o</i> -tolylazo)-5-isoxazolone
	4-Methyl	3-Methyl-4-(<i>p</i> -tolylazo)-5-isoxazolone
	2-Methoxy	3-Methyl-4-(<i>o</i> -anisylazo)-5-isoxazolone
	α -Naphthylamine	3-Methyl-4-(α -naphthylazo)-5-isoxazolone
	β -Naphthylamine	3-Methyl-4-(β -naphthylazo)-5-isoxazolone
3-Phenyl-5-isoxazolone	—	3-Phenyl-4-phenylazo-5-isoxazolone
3-(<i>m</i> -Tolyl)-5-isoxazolone	—	3-(<i>m</i> -Tolyl)-4-phenylazo-5-isoxazolone
3-(<i>p</i> -Tolyl)-5-isoxazolone	—	3-(<i>p</i> -Tolyl)-4-phenylazo-5-isoxazolone
3-(<i>m</i> -Chlorophenyl)-5-isoxazolone	4-Nitro	3-(<i>m</i> -Chlorophenyl)-4-(<i>p</i> -nitrophenylazo)-5-isoxazolone
3-(<i>m</i> -Nitrophenyl)-5-isoxazolone	4-Nitro	3-(<i>m</i> -Nitrophenyl)-4-(<i>p</i> -nitrophenylazo)-5-isoxazolone
3-Anilino-5-isoxazolone	—	3-Anilino-4-phenylazo-5-isoxazolone
3-Methyl-5-iminoisoxazole	—	3-Methyl-4-phenylazo-5-iminoisoxazole
2-Benzyl-4-imidazolone	4-Nitro	3-Benzyl-5-(<i>p</i> -nitrophenylazo)-4-imidazolone
1,2,3-Triazol-5-one	4-Methyl	4-(<i>p</i> -Tolylazo)-1,2,3-triazol-5-one
1-Carboxymethyl-1,2,3,4-triazol-5-one	4-Methyl	1-Carboxymethyl-4-(<i>p</i> -tolylazo)-1,2,3-triazol-5-one
1-Phenyl-1,2,3-triazol-5-one	—	1-Phenyl-4-phenylazo-1,2,3-triazol-5-one
1-Acetylbenzalhydrazide-1,2,3-triazol-5-one	4-Methyl	1-Acetylbenzalhydrazide-4-(<i>p</i> -tolylazo)-1,2,3-triazol-5-one
1-Acetylglycinbenzalhydrazide-1,2,3-triazol-5-one	4-Methyl	1-Acetylglycinbenzalhydrazide-4-(<i>p</i> -tolylazo)-1,2,3-triazol-5-one
Barbituric acid	—	5-Oxobarbituric acid phenylhydrazone (quant.)
	2-Nitro	5-Oxobarbituric acid <i>o</i> -nitrophenylhydrazone

References

450

451, 227, 452

227

227

227

227

227

453

454

454

455

455

456

90

457

458

458

459

460

460

461

461

4-Nitro	5-Oxobarbituric acid	<i>p</i> -nitrophenylhydrazine	461
4-Sulfamyl	5-Oxobarbituric acid	<i>p</i> -sulfamylphenylhydrazine	244
4-(<i>p</i> -Dimethyl-sulfamylphenyl)-sulfamyl	5-Oxobarbituric acid	<i>p</i> -(<i>p</i> -dimethylsulfamylphenyl)-sulfamylphenylhydrazine	244
—	N,N'-Diphenylbarbituric acid		462
4-Nitro	N,N'-Diphenyl-5-oxobarbituric acid	phenylhydrazine	462
—	N,N'-Diphenyl-5-benzylbarbituric acid		462
—	N,N'-Diphenyl-5-benzyl-5-phenylazobarbituric acid		462
4-Nitro	N,N'-Diphenyl-5-benzyl-5-(<i>p</i> -nitrophenylazo)-barbituric acid		462
4-Nitro	N,N'-Diphenyl-5-diphenylmethyl-5-(<i>p</i> -nitrophenylazo)-barbituric acid		462
—	N,N'-Diphenylthio-barbituric acid		463
4-Nitro	N,N'-Diphenylthio-barbituric acid		463
—	N,N'-Diphenyl-5-phenylazothio-barbituric acid		463
—	N,N'-Diphenyl-5-(<i>p</i> -nitrophenylazo)thio-barbituric acid		463
—	N,N'-Diphenyl-5-diphenylmethyl-5-phenylazothio-barbituric acid		464
4-Nitro	3-Phenylazo-2-thianaphthene		464
—	3-(<i>p</i> -Nitrophenylazo)-2-thianaphthene		464
—	3-(α -Naphthylazo)-2-thianaphthene		464
—	3-(β -Naphthylazo)-2-thianaphthene		465
4-Nitro	2-(<i>p</i> -Nitrophenylazo)-3-thianaphthene		466
—	2-Phenylazo-5-methyl-3-thianaphthene		467
—	2-Phenylazo-3-selenanaphthene		77
4-Bromo	3-(<i>p</i> -Bromophenylazo)-6-nitroindole		468
—	1-Phenyl-3-phenylazooxindole		469
—	2-Phenylazooxindole		469

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued
B. Miscellaneous Heterocyclic Compounds—Continued

Heterocyclic Reactant	Substituent(s) in Aniline*	Product (Yield, %)	References
Homophthalimide			470, 471, 472
	2-Methyl	α -Phenylazohomophthalimide	472
	3-Methyl	α -(<i>o</i> -Tolylazo)homophthalimide	472
	4-Methyl	α -(<i>m</i> -Tolylazo)homophthalimide	472
	2-Chloro	α -(<i>o</i> -Chlorophenylazo)homophthalimide	472
	2-Nitro	α -(<i>o</i> -Nitrophenylazo)homophthalimide	472
	4-Nitro	α -(<i>p</i> -Nitrophenylazo)homophthalimide	472
	2-Carboxy	α -(<i>o</i> -Carboxyphenylazo)homophthalimide	472
	3-Carboxy	α -(<i>m</i> -Carboxyphenylazo)homophthalimide	472
	4-Sulfo	α -(<i>p</i> -Sulfophenylazo)homophthalimide	473
	2,4-Dimethyl	α -(2,4-Dimethylphenylazo)homophthalimide	472
	4-Methyl-2-nitro	α -(4-Methyl-2-nitrophenylazo)homophthalimide	472
	4-Methyl-3-nitro	α -(4-Methyl-3-nitrophenylazo)homophthalimide	472
	α -Naphthylamine	α -(1-Naphthylazo)homophthalimide	472
	β -Naphthylamine	α -(2-Naphthylazo)homophthalimide	472
	4-Sulfo-1-naphthylamine	α -(4-Sulfo-1-naphthylazo)homophthalimide	473
	6,8-Disulfo-2-naphthylamine	α -(6,8-Disulfo-2-naphthylazo)homophthalimide	473
	2-Hydroxy-4-sulfo-1-naphthylamine	α -(2-Hydroxy-4-sulfo-1-naphthylazo)homophthalimide	473
Benzidine			
	3,3'-Dimethylbenzidine	α,α' -(4,4'-Biphenylenedisulfo)bis(homophthalimide)	472
	3,3'-Dimethylbenzidine	α,α' -(3,3'-Dimethyl-4,4'-biphenylenedisulfo)bis(homophthalimide)	472
	3,3'-Trimethoxybenzidine	α,α' -(3,3'-Dimethoxy-4,4'-biphenylenedisulfo)bis(homophthalimide)	472

N-Phenylhomophthalimide	α -Phenylazo-N-phenylhomophthalimide	474
4-Hydroxycoumarin	3-Phenylazo-4-hydroxycoumarin (91)	475
	3-(<i>p</i> -Tolylazo)-4-hydroxycoumarin (88)	475
	3-(<i>p</i> -Nitrophenylazo)-4-hydroxycoumarin (75)	475
	3-(<i>p</i> -Sulfophenylazo)-4-hydroxycoumarin (10)	475
	3-(<i>p</i> -Sulfamylphenylazo)-4-hydroxycoumarin (50)	475
1-Methyl-4-hydroxyacetophenyl Glutaconic anhydride	1-Methyl-3- <i>o</i> -nitrophenylazo-4-hydroxyacetophenyl	476a
	γ -Ketoglutaconic anhydride phenylhydrazine (87)	475a
	γ -Ketoglutaconic anhydride <i>o</i> -tolylhydrazine (57)	475a
	γ -Ketoglutaconic anhydride <i>p</i> -tolylhydrazine (79)	475a
	γ -Ketoglutaconic anhydride <i>o</i> -anisylhydrazine (56)	475a
	γ -Ketoglutaconic anhydride <i>p</i> -dimethylaminophenyl- hydrazine (64)	475a
2-Carboxy	γ -Ketoglutaconic anhydride <i>o</i> -carboxyphenyl- hydrazine (80)	475a
α -Naphthylamine	γ -Ketoglutaconic anhydride α -naphthylhydrazine (86)	475a
β -Naphthylamine	γ -Ketoglutaconic anhydride β -naphthylhydrazine (87)	475a
—	γ -Keto- β -methylglutaconic anhydride phenylhydrazine (70)	8b
2-Methoxy	γ -Keto- β -methylglutaconic anhydride <i>o</i> -anisylhydrazine (62)	8b
4-Methoxy	γ -Keto- β -methylglutaconic anhydride <i>p</i> -anisylhydrazine (40)	8b
2-Nitro	γ -Keto- β -methylglutaconic anhydride <i>o</i> -nitrophenyl- hydrazine (64)	8b
4-Dimethylamino	γ -Keto- β -methylglutaconic anhydride <i>p</i> -dimethylamino- phenylhydrazine (72)	8b
4-Diethylamino	γ -Keto- β -methylglutaconic anhydride <i>p</i> -diethylamino- phenylhydrazine (71)	8b

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE X—Continued
 B. Miscellaneous Heterocyclic Compounds—Continued

Heterocyclic Reactant (Cont.)	Substituent(s) in Aniline*	Product (Yield, %)	References
β -Methylglutaconic anhydride	4-Sulfo	γ -Keto- β -methylglutaconic anhydride <i>p</i> -sulfophenyl- hydrazine (85)	8b
	3-Trifluoromethyl	γ -Keto- β -methylglutaconic anhydride <i>m</i> -trifluoromethyl- phenylhydrazine (65)	8b
	2,4-Dinitro	γ -Keto- β -methylglutaconic anhydride 2,4-dinitrophenyl- hydrazine (69)	8b
	α -Naphthylamine	γ -Keto- β -methylglutaconic anhydride α -naphthyl- hydrazine (85)	8b
	β -Naphthylamine	γ -Keto- β -methylglutaconic anhydride β -naphthyl- hydrazine (85)	8b
	—	β -Chloro- γ -ketoglutaconic anhydride phenylhydrazine	476b
	—	β -Carboxy- γ -ketoglutaconic anhydride phenylhydrazine (84)	476c
	—	β -Carbomethoxy- γ -ketoglutaconic anhydride phenyl- hydrazine (70)	476c
	—	3-Phenylazo-4H-pyrido[1,2- <i>a</i>]pyrimidin-4-one (85)	300b
4-Carboxy	—	3-(<i>p</i> -Carboxyphenylazo)-4H-pyrido[1,2- <i>a</i>]pyrimidin-4-one (96)	300b
4-Carbomethoxy	—	3-(<i>p</i> -Carbomethoxyphenylazo)-4H-pyrido[1,2- <i>a</i>]pyrimidin-4-one (70)	300b
4-Carbethoxy	—	3-(<i>p</i> -Carbethoxyphenylazo)-4H-pyrido[1,2- <i>a</i>]pyrimidin-4-one	300b
4-Sulfo	—	3-(<i>p</i> -Sulfophenylazo)-4H-pyrido[1,2- <i>a</i>]pyrimidin-4-one (93)	300b

Note: References 177-480 are on pp. 136-142.

* The full name is given when it is awkward to name the arylamine as a derivative of aniline.

TABLE XI
COUPLING OF DIAZONIUM SALTS WITH MISCELLANEOUS COMPOUNDS

Reactant	Substituent in Aniline	Product (Yield, %)	References
Diacetamide	4-Nitro	Chloroformaldehyde <i>p</i> -nitrophenylhydrazine* (85)	476 <i>d</i>
Acetaldehyde	—	<i>N,N'</i> -Diphenyl- <i>C</i> -phenylazoformazan (20-30)	153, 27
Ketene diethylacetal	—	1-Phenyl-4-ethoxy-6-pyridazone (35)	477
	4-Ethoxy	1- <i>p</i> -Ethoxyphenyl-4-ethoxy-6-pyridazone† (21)	477
	4-Nitro	1- <i>p</i> -Nitrophenyl-4-ethoxy-6-pyridazone (25)	477
	4-Carboxy	1- <i>p</i> -Carbethoxyphenyl-4-ethoxy-6-pyridazone (33)	477
Ethyl β -aminocrotonate	—	Ethyl α -phenylazo- β -aminocrotonate (52)	478
Ethyl β -methylaminocrotonate	—	Ethyl α -phenylazo- β -methylaminocrotonate (51)	478
Ethyl β -diethylaminocrotonate	—	1-Phenyl-3-diethylamino-3-methyl-4-phenylazo-5-ethoxypyrazoline (75)	479
Bis(phenylsulfinyl)methane	—	Bis(phenylsulfinyl)formaldehyde phenylhydrazine	480
1-(2-Methylpropenyl)piperidine	4-Chloro	Acetone <i>p</i> -chlorophenylhydrazine	130 <i>a</i>
	4-Nitro	Acetone <i>p</i> -nitrophenylhydrazine	130 <i>a</i>
	4-Methoxy	1,2-Butanedione 2- <i>p</i> -anisylhydrazine (53)	130 <i>a</i>
1-(1-Butenyl)piperidine	4-Chloro	1,2-Butanedione 2- <i>p</i> -chlorophenylhydrazine (65)	130 <i>a</i>
	4-Nitro	1,2-Butanedione 2- <i>p</i> -nitrophenylhydrazine (41)	130 <i>a</i>
	4-Methoxy	Phenylglyoxal β - <i>p</i> -anisylhydrazine (76)	130 <i>a</i>
<i>N,N</i> -Dimethylstyrylamine	4-Chloro	Phenylglyoxal β - <i>p</i> -chlorophenylhydrazine (90)	130 <i>a</i>
	4-Nitro	Phenylglyoxal β - <i>p</i> -nitrophenylhydrazine (94)	130 <i>a</i>
	4-Carboxy	Phenylglyoxal β - <i>p</i> -carboxyphenylhydrazine (89)	130 <i>a</i>
	4-Nitro	Acetophenone <i>p</i> -nitrophenylhydrazine (87)	130 <i>a</i>
1-(β -Methylstyryl)piperidine	4-Carboxy	Acetophenone <i>p</i> -carboxyphenylhydrazine (95)	130 <i>a</i>
	2,4-Dinitro	Acetophenone 2,4-dinitrophenylhydrazine (97)	130 <i>a</i>

Note: References 177-480 are on pp. 136-142.

* The reaction was run in methanol saturated with lithium chloride.

† Sixteen per cent of *N,N'*-di-*p*-ethoxyphenyl-*C*-carbethoxyformazan was also formed.

REFERENCES FOR TABLES I-XI

- ¹⁰⁰ Favrel, *Bull. soc. chim. France*, [5], **1**, 981 (1934).
- ¹⁰¹ Benary, Reiter, and Soenderop, *Ber.*, **50**, 65 (1917).
- ¹⁰² Jerchel and Fischer, *Ann.*, **563**, 208 (1949).
- ¹⁰³ Bamberger and Kuhlemann, *Ber.*, **26**, 2978 (1893).
- ¹⁰⁴ Wolff, *Ann.*, **317**, 1 (1901).
- ¹⁰⁵ Wislicenus and Schöllkopf, *J. prakt. Chem.*, [2], **95**, 269 (1917).
- ¹⁰⁶ Borsche, Stackmann, and Makaroff-Semljanski, *Ber.*, **49**, 2222 (1916).
- ¹⁰⁷ Kröhnke and Kübler, *Ber.*, **70**, 538 (1937).
- ¹⁰⁸ Kowjalgi and Iyer, *Current Sci. India*, **19**, 210 (1950) [*C. A.*, **45**, 863 (1951)].
- ¹⁰⁹ Iyer and Kowjalgi, *J. Indian Inst. Sci.*, **34**, 81 (1952) [*C. A.*, **46**, 8857 (1952)].
- ¹¹⁰ Beyer and Claisen, *Ber.*, **21**, 1697 (1888).
- ¹¹¹ Bülow and Schlotterbeck, *Ber.*, **35**, 2187 (1902).
- ¹¹² Bülow and Spengler, *Ber.*, **58**, 1375 (1925).
- ¹¹³ Chattaway and Ashworth, *J. Chem. Soc.*, **1934**, 930.
- ¹¹⁴ Favrel, *Bull. soc. chim. France*, [3], **27**, 328 (1902).
- ¹¹⁵ Favrel, *Compt. rend.*, **128**, 318 (1899).
- ¹¹⁶ Reilly, Daly, and Drumm, *Proc. Roy. Irish Acad.*, **40B**, 94 (1931) [*C. A.*, **26**, 452 (1932)].
- ¹¹⁷ Morgan and Reilly, *J. Chem. Soc.*, **103**, 808 (1913).
- ¹¹⁸ Reilly and MacSweeney, *Proc. Roy. Irish Acad.*, **39B**, 497 (1930) [*C. A.*, **25**, 1523 (1931)].
- ¹¹⁹ Morgan and Ackerman, *J. Chem. Soc.*, **123**, 1308 (1923).
- ¹²⁰ Reilly and Drumm, *J. Chem. Soc.*, **1926**, 1729.
- ¹²¹ Morgan and Drew, *J. Chem. Soc.*, **119**, 610 (1921).
- ¹²² Sieglitz and Horn, *Chem. Ber.*, **84**, 607 (1951).
- ¹²³ Claisen and Ehrhardt, *Ber.*, **22**, 1009 (1889).
- ¹²⁴ Feist and Belart, *Ber.*, **28**, 1817 (1895).
- ¹²⁵ Mullen and Crowe, *J. Chem. Soc.*, **1927**, 1751.
- ¹²⁶ Bamberger and Witter, *Ber.*, **26**, 2786 (1893).
- ¹²⁷ Bamberger and Witter, *J. prakt. Chem.*, [2], **65**, 139 (1902).
- ¹²⁸ Chattaway and Ashworth, *J. Chem. Soc.*, **1933**, 1624.
- ¹²⁹ Bülow, *Ber.*, **32**, 2637 (1899).
- ¹³⁰ Bülow and Busse, *Ber.*, **39**, 2459 (1906).
- ¹³¹ Sachs and Herold, *Ber.*, **40**, 2714 (1907).
- ¹³² Kostanecki and Tambor, *Ber.*, **35**, 1679 (1902).
- ¹³³ Bülow and Sautermeister, *Ber.*, **37**, 354 (1904).
- ¹³⁴ Morgan and Porter, *J. Chem. Soc.*, **125**, 1269 (1924).
- ¹³⁵ Bülow and Riess, *Ber.*, **35**, 3900 (1902).
- ¹³⁶ Bülow and Grotowsky, *Ber.*, **34**, 1479 (1901).
- ¹³⁷ Anand, Patel, and Venkataraman, *Proc. Indian Acad. Sci.*, **28A**, 545 (1948) [*C. A.*, **43**, 5778 (1949)].
- ¹³⁸ Claisen and Roosen, *Ann.*, **278**, 274 (1894).
- ¹³⁹ Favrel and Jean, *Bull. soc. chim. France*, [4], **37**, 1238 (1925).
- ¹⁴⁰ Bülow, *Ber.*, **37**, 2198 (1904).
- ¹⁴¹ Bülow and Nottbohm, *Ber.*, **36**, 2695 (1903).
- ¹⁴² Bülow and Nottbohm, *Ber.*, **36**, 392 (1903).
- ¹⁴³ Krishnan, Iyer, and Guha, *Science and Culture India*, **11**, 567 (1946) [*C. A.*, **40**, 5712 (1946)].
- ¹⁴⁴ Vorländer and Erig, *Ann.*, **294**, 302 (1897).
- ¹⁴⁵ Boehm, *Ann.*, **318**, 230 (1901).
- ¹⁴⁶ Boehm, *Ann.*, **329**, 269 (1903).
- ¹⁴⁷ Rabe, *Ber.*, **31**, 1896 (1898).
- ¹⁴⁸ Osborn and Schofield, *J. Chem. Soc.*, **1955**, 2100.
- ¹⁴⁹ den Otter, *Rec. trav. chim.*, **57**, 427 (1938).
- ¹⁵⁰ Bamberger, *Ber.*, **24**, 3260 (1891).

- 189 Schiff and Viciani, *Gazz. chim. ital.*, **27**, II, 70 (1897).
- 190 Chattaway and Ashworth, *J. Chem. Soc.*, **1933**, 475.
- 191 Bamberger, *Ber.*, **17**, 2415 (1884).
- 192 Chattaway and Lye, *Proc. Roy. Soc. London*, **A135**, 282 (1932) [*C. A.*, **26**, 5074 (1932)].
- 193 Wolff and Lüttringhaus, *Ann.*, **312**, 155 (1900).
- 194 Bamberger and Schmidt, *Ber.*, **34**, 2001 (1901).
- 195a Wizinger and Herzog, *Helv. Chim. Acta*, **36**, 531 (1953).
- 196 Michael, *Ber.*, **38**, 2096 (1905).
- 197 von Richter and Münzer, *Ber.*, **17**, 1926 (1884).
- 198 Bülow and Neber, *Ber.*, **45**, 3732 (1912).
- 199 Goldberg and Kelly, *J. Chem. Soc.*, **1948**, 1919.
- 200 Bülow and Schaub, *Ber.*, **41**, 2355 (1908).
- 201 Bülow and Engler, *Ber.*, **51**, 1246 (1918).
- 202 Kjellin, *Ber.*, **30**, 1965 (1897).
- 203a Le Bris and Wahl, *Compt. rend.*, **241**, 1143 (1955).
- 204 von Pechmann and Wedekind, *Ber.*, **28**, 1688 (1895).
- 205 Bülow, *Ber.*, **31**, 3122 (1898).
- 206 Griess, *Ber.*, **18**, 960 (1885).
- 207 Bülow, *Ber.*, **33**, 187 (1900).
- 208 Mossini, *Ann. chim. farm.*, Dec. **1939**, 47 [*C. A.*, **34**, 2175 (1940)].
- 209 Chattaway and Parkes, *J. Chem. Soc.*, **1935**, 1005.
- 210 Chattaway and Daldy, *J. Chem. Soc.*, **1928**, 2756.
- 211 Chattaway, Ashworth, and Grimwade, *J. Chem. Soc.*, **1935**, 117.
- 212 Chattaway and Ashworth, *J. Chem. Soc.*, **1933**, 475.
- 213 Oddo, *Gazz. chim. ital.*, **21**, I, 264 (1891).
- 214 Saunders, *J. Chem. Soc.*, **117**, 1264 (1920).
- 215 Morgan and Read, *J. Chem. Soc.*, **121**, 2709 (1922).
- 216 Bülow, *Ber.*, **44**, 601 (1911).
- 217 Bülow and Baur, *Ber.*, **58**, 1926 (1925).
- 218 Wedekind, *Ann.*, **295**, 324 (1897).
- 219 Wizinger and Herzog, *Helv. Chim. Acta*, **34**, 1202 (1951).
- 220 Bülow and von Reden, *Ber.*, **31**, 2574 (1898).
- 221 Favrel, *Compt. rend.*, **145**, 194 (1907).
- 222 Favrel, *Bull. soc. chim. France*, [4], **1**, 1238 (1907).
- 223 Wolff and Fertig, *Ann.*, **313**, 12 (1900).
- 224 Wahl and Doll, *Bull. soc. chim. France*, [4], **13**, 265 (1913).
- 225 Wahl, *Compt. rend.*, **147**, 72 (1908).
- 226 Wahl, *Bull. soc. chim. France*, [4], **3**, 946 (1908).
- 227 Bamberger and Calman, *Ber.*, **18**, 2563 (1885).
- 228 Stierlin, *Ber.*, **21**, 2120 (1888).
- 229 Wahl, *Bull. soc. chim. France*, [4], **1**, 729 (1907).
- 230 Ciusa, *Gazz. chim. ital.*, **50**, I, 194 (1920).
- 231 Bülow and Busse, *Ber.*, **39**, 3861 (1906).
- 232 Wahl and Silberzweig, *Bull. soc. chim. France*, [4], **11**, 61 (1912).
- 233 Wahl and Rolland, *Ann. chim. Paris*, [10], **10**, 5 (1928).
- 234 Rabischong, *Bull. soc. chim. France*, [3], **31**, 87 (1904).
- 235 Chattaway and Humphrey, *J. Chem. Soc.*, **1927**, 2793.
- 236 Chattaway and Humphrey, *J. Chem. Soc.*, **1927**, 1323.
- 237 Rabischong, *Bull. soc. chim. France*, [3], **27**, 982 (1902).
- 238 Sonn, *Ann.*, **518**, 290 (1935).
- 239 Tamburello and Carapelle, *Gazz. chim. ital.*, **37**, I, 561 (1907).
- 240 Dieckmann, *Ber.*, **45**, 2689 (1912).
- 241 Dieckmann, *Ber.*, **44**, 975 (1911).
- 242 Bülow, *Ber.*, **40**, 3787 (1907).
- 243 Bülow, *Ber.*, **41**, 641 (1908).
- 244 Bülow and Bozenhardt, *Ber.*, **43**, 234 (1910).

- ²⁸¹ Knorr and Reuter, *Ber.*, **27**, 1169 (1894).
- ²⁸² Andrisano and Pentimalli, *Ann. chim. Rome*, **40**, 292 (1950) [*C. A.*, **45**, 6384 (1951)].
- ²⁸³ Andrisano, *Boll. sci. fac. chim. ind. Bologna*, **7**, 58 (1949) [*C. A.*, **44**, 9404 (1950)].
- ²⁸⁴ Morgan and Davies, *J. Chem. Soc.*, **123**, 228 (1923).
- ²⁸⁵ Seidel, *Ber.*, **59**, 1894 (1926).
- ²⁸⁶ Bulow and Dick, *Ber.*, **57**, 1281 (1924).
- ²⁸⁷ Andrisano and Passerini, *Ann. chim. Rome*, **40**, 439 (1950) [*C. A.*, **45**, 8775 (1951)].
- ²⁸⁸ Chelintsev, *J. Gen. Chem. U.S.S.R.*, **14**, 941 (1944) [*C. A.*, **39**, 4611 (1945)].
- ²⁸⁹ Petersen, *Chem. Ber.*, **83**, 551 (1950).
- ²⁹⁰ Andrisano and Marchi, *Ann. chim. Rome*, **40**, 442 (1950) [*C. A.*, **45**, 8775 (1951)].
- ^{290a} Abramovitch and Schofield, *J. Chem. Soc.*, **1955**, 2326.
- ²⁹¹ Busch and Frey, *Ber.*, **36**, 1362 (1903).
- ²⁹² Fusco and Romani, *Gazz. chim. ital.*, **78**, 332 (1948).
- ²⁹³ Bulow and Ganghofer, *Ber.*, **37**, 4169 (1904).
- ²⁹⁴ Favrel, *Bull. soc. chim. France*, [3], **27**, 313 (1902).
- ²⁹⁵ Favrel, *Compt. rend.*, **128**, 829 (1899).
- ²⁹⁶ Meyer, *Ber.*, **24**, 1241 (1891).
- ²⁹⁷ Henrich and Thomas, *Ber.*, **40**, 4924 (1907).
- ²⁹⁸ Henrich, *Monatsh.*, **20**, 537 (1899).
- ²⁹⁹ Henrich, *Ber.*, **35**, 1663 (1902).
- ^{300a} Shaw, *J. Biol. Chem.*, **185**, 439 (1950).
- ^{300b} Snyder and Robison, *J. Am. Chem. Soc.*, **74**, 4910 (1952).
- ^{300c} Snyder and Robison, *J. Am. Chem. Soc.*, **74**, 5945 (1952).
- ³⁰¹ Meyer, *Ber.*, **21**, 1306 (1888).
- ³⁰² Hausknecht, *Ber.*, **22**, 324 (1889).
- ³⁰³ Wizinger and Biro, *Helv. Chim. Acta*, **32**, 901 (1949).
- ³⁰⁴ Haller, *Compt. rend.*, **106**, 1171 (1888).
- ³⁰⁵ Favrel, *Bull. soc. chim. France*, [3], **27**, 104 (1902).
- ³⁰⁶ Favrel, *Compt. rend.*, **127**, 116 (1898).
- ³⁰⁷ Krückeberg, *J. prakt. Chem.*, [2], **46**, 579 (1892).
- ³⁰⁸ Krückeberg, *J. prakt. Chem.*, [2], **47**, 591 (1893).
- ³⁰⁹ Weissbach, *J. prakt. Chem.*, [2], **57**, 206 (1898).
- ³¹⁰ Lax, *J. prakt. Chem.*, [2], **63**, 1 (1901).
- ³¹¹ Marquardt, *J. prakt. Chem.*, [2], **52**, 160 (1895).
- ³¹² Uhlmann, *J. prakt. Chem.*, [2], **51**, 217 (1895).
- ³¹³ Bulow and Neber, *Ber.*, **49**, 2179 (1916).
- ³¹⁴ Favrel, *Compt. rend.*, **122**, 844 (1896).
- ³¹⁵ Bowack and Lapworth, *J. Chem. Soc.*, **85**, 42 (1904).
- ³¹⁶ Perkin, *J. Chem. Soc.*, **43**, 111 (1883).
- ³¹⁷ Haller, *Compt. rend.*, **108**, 1116 (1889).
- ³¹⁸ von Meyer, *J. prakt. Chem.*, [2], **90**, 1 (1914).
- ³¹⁹ Benary and Hosenfeld, *Ber.*, **55**, 3417 (1922).
- ³²⁰ Backer, *Rec. trav. chim.*, **70**, 892 (1951).
- ³²¹ Finzi and Bottiglieri, *Gazz. chim. ital.*, **48**, II, 113 (1918).
- ³²² Bamberger and Schmidt, *Ber.*, **34**, 574 (1901).
- ³²³ Bamberger, Padova, and Ormerod, *Ann.*, **446**, 260 (1925).
- ^{323a} Jerchel and Elder, *Chem. Ber.*, **88**, 1284 (1955).
- ^{323b} Robbins and Schofield, *J. Chem. Soc.*, **1957**, 3186.
- ³²⁴ Deussen and Hunsicker, *J. Am. Chem. Soc.*, **66**, 23, 69 (1944) [*C. A.*, **38**, 2000 (1944)].
- ³²⁵ Kappeler, *Ber.*, **12**, 2285 (1879).
- ³²⁶ Bamberger, *Ber.*, **31**, 2626 (1898).
- ³²⁷ Barbieri, *Ber.*, **9**, 386 (1876).
- ³²⁸ Wald, *Ber.*, **9**, 393 (1876).
- ³²⁹ Hallmann, *Ber.*, **9**, 389 (1876).
- ³³⁰ Bamberger and Frei, *Ber.*, **35**, 82 (1902).

- 331 Bamberger and Frei, *Ber.*, **36**, 3833 (1903).
- 332 Oddo and Ampola, *Gazz. chim. ital.*, **23**, I, 257 (1893).
- 333 Feasley and Degering, *J. Org. Chem.*, **8**, 12 (1943).
- 334 Askenasy and Meyer, *Ber.*, **25**, 1701 (1892).
- 335 Duden, *Ber.*, **26**, 3003 (1893).
- 336 Keppler and Meyer, *Ber.*, **25**, 1709 (1892).
- 337 von Braun and Sobecki, *Ber.*, **44**, 2526 (1911).
- 338 von Braun and Danziger, *Ber.*, **46**, 103 (1913).
- 339 Russanow, *Ber.*, **25**, 2635 (1892).
- 340 Kimich, *Ber.*, **10**, 140 (1877).
- 341 Wieland, *Ann.*, **328**, 250 (1903).
- 342 Meyer and Wertheimer, *Ber.*, **47**, 2374 (1914).
- 343 Gold and Levine, *J. Org. Chem.*, **16**, 1507 (1951).
- 344 Demuth and Meyer, *Ann.*, **256**, 28 (1890).
- 345 Chattaway, Drewitt, and Parkes, *J. Chem. Soc.*, **1936**, 1693.
- 346 Canonica, *Gazz. chim. ital.*, **79**, 738 (1949).
- 347 Meisenheimer and Heim, *Ber.*, **38**, 466 (1905).
- 348 Holleman, *Rec. trav. chim.*, **13**, 403 (1894).
- 349 Bamberger, *Ber.*, **33**, 1781 (1900).
- 350 Ponzio, *Gazz. chim. ital.*, **42**, I, 525 (1912).
- 351 Bamberger and Scheutz, *Ber.*, **34**, 2023 (1901).
- 352 Bamberger and Pemsel, *Ber.*, **36**, 57 (1903).
- 353 Parkes and Williams, *J. Chem. Soc.*, **1934**, 67.
- 354 von Braun and Kruber, *Ber.*, **45**, 384 (1912).
- 355 Ponzio, *Gazz. chim. ital.*, **38**, I, 509 (1908).
- 356 Ponzio and Charrier, *Gazz. chim. ital.*, **39**, I, 625 (1909).
- 357 Ponzio, *Gazz. chim. ital.*, **39**, I, 559 (1909).
- 358 Ponzio and Charrier, *Gazz. chim. ital.*, **38**, I, 526 (1908).
- 359 Sonn and Schellenberg, *Ber.*, **50**, 1513 (1917).
- 360 Arbuzov and Rafikov, *J. Gen. Chem. U.S.S.R.*, **7**, 2195 (1937) [*C. A.*, **32**, 515 (1938)].
- 361a Meyer, Irschick, and Schlösser, *Ber.*, **47**, 1741 (1914).
- 361b Bachman and Hatton, *J. Am. Chem. Soc.*, **66**, 1513 (1944).
- 362 Thiele, *Ber.*, **33**, 666 (1900).
- 363 Süss, *Ann.*, **556**, 85 (1944).
- 364 Quilico and Freri, *Gazz. chim. ital.*, **62**, 253 (1932).
- 365 Terent'ev and Zengelin, *Sci. Repts. Moscow State Univ.*, 1936, No. 6, 257 [*C. A.*, **32**, 2516 (1938)].
- 366 Allen, Eliot, and Bell, *Can. J. Res.*, **17B**, 75 (1939).
- 367a Pierrot and Wahl, *Compt. rend.*, **240**, 879 (1955).
- 367b Pierrot and Wahl, *Compt. rend.*, **239**, 1049 (1954).
- 368 Busch and Klett, *Ber.*, **25**, 2847 (1892).
- 369 Jacobs, Winstein, Henderson, and Spaeth, *J. Am. Chem. Soc.*, **68**, 1310 (1946).
- 370 Atkinson and Simpson, *J. Chem. Soc.*, **1947**, 808.
- 371 Schofield and Swain, *J. Chem. Soc.*, **1949**, 1367.
- 372 Simpson, *J. Chem. Soc.*, **1946**, 673.
- 373 Simpson, *J. Chem. Soc.*, **1943**, 447.
- 374 Krahler and Burger, *J. Am. Chem. Soc.*, **63**, 2367 (1941).
- 375 Witt, Nölting, and Grandmougin, *Ber.*, **23**, 3635 (1890).
- 376 Michel and Grandmougin, *Ber.*, **26**, 2349 (1893).
- 377 von Auwers and Schwegler, *Ber.*, **53**, 1211 (1920).
- 378 Gabriel and Stelzner, *Ber.*, **29**, 303 (1896).
- 379 Zincke and Malkomesius, *Ann.*, **339**, 218 (1905).
- 380 [Zincke and Malkomesius, *Ann.*, **339**, 218 (1905).]
- 381 Petitcolas and Sureau, *Bull. soc. chim. France*, **1950**, 466.
- 382 Zincke and Kuchenbecker, *Ann.*, **339**, 226 (1905).

- ³⁸² Morgan and Davies, *J. Chem. Soc.*, **123**, 228 (1923).
³⁸³ Dadswell and Kenner, *J. Chem. Soc.*, **1927**, 580.
³⁸⁴ Duval, *Compt. rend.*, **154**, 780 (1912).
³⁸⁵ Duval, *Compt. rend.*, **146**, 1407 (1908).
³⁸⁶ Duval, *Compt. rend.*, **144**, 1222 (1907).
³⁸⁷ Capka, *Chem. Zvesti*, **2**, 1 (1948) [*C. A.*, **44**, 1523 (1950)].
³⁸⁸ Bamberger and Pemsel, *Ber.*, **36**, 85 (1903).
³⁸⁹ Jerchel, *Ber.*, **75B**, 75 (1942).
^{389a} Nineham, Pain, and Slack, *J. Chem. Soc.*, **1954**, 1568.
^{389b} Lacroix, Haudry, and Schabert, *Helvetica Chim. Acta*, **28**, 289 (1952) [*C. A.*, **48**, 10677 (1954)].
^{389c} Libman, Nineham, and Slack, *J. Chem. Soc.*, **1954**, 1565.
³⁹⁰ Ragno and Orsini, *Gazz. chim. ital.*, **78**, 228 (1948).
³⁹¹ Ragno and Bruno, *Gazz. chim. ital.*, **77**, 12 (1947).
³⁹² Bensch and Keskin, *Rev. f. v. sci. univ. Istanbul*, **9A**, No. 1, 30 (1944) [*C. A.*, **40**, 1319 (1946)].
³⁹³ Hausser, Jerchel, and Kuhn, *Chem. Ber.*, **82**, 515 (1949).
^{393a} Duffin and Kendall, *J. Chem. Soc.*, **1954**, 408.
³⁹⁴ Wislicenus, *Ber.*, **25**, 3456 (1892).
³⁹⁵ Mattson, Jensen, and Dutcher, *J. Am. Chem. Soc.*, **70**, 1284 (1948).
^{395a} Ashley, Davis, Nineham, and Slack, *J. Chem. Soc.*, **1953**, 3881.
³⁹⁶ Fox and Atkinson, *J. Am. Chem. Soc.*, **72**, 3629 (1950).
³⁹⁷ Wedekind, *Ber.*, **32**, 1918 (1899).
³⁹⁸ Jerchel and Fischer, *Ann.*, **563**, 200 (1949).
^{398a} Ried, Gick, and Oertel, *Ann.*, **581**, 29 (1953).
^{398b} Beyer and Pyl, *Chem. Ber.*, **87**, 1505 (1954).
^{398c} Tsou, Cheng, Nachlas, and Seligman, *J. Am. Chem. Soc.*, **78**, 6139 (1956).
^{398d} Ried and Hillenbrand, *Ann.*, **581**, 44 (1953).
³⁹⁹ Ludolphy, *Chem. Ber.*, **84**, 385 (1951).
⁴⁰⁰ Seyhan, *Rev. fac. sci. univ. Istanbul*, **17A**, 182 (1952) [*C. A.*, **47**, 12390 (1953)].
⁴⁰¹ von Pechmann, *Ber.*, **29**, 2161 (1896).
⁴⁰² Wedekind, *Ber.*, **30**, 444 (1897).
^{402a} Cottrell, Pain, and Slack, *J. Chem. Soc.*, **1954**, 2968.
^{402b} Seyhan, *Chem. Ber.*, **87**, 1124 (1954).
^{402d} Seyhan, *Chem. Ber.*, **88**, 646 (1955).
^{402e} Seyhan, *Chem. Ber.*, **87**, 396 (1954).
^{402f} Wahl and Le Bris, *Bull. soc. chim. France*, **1954**, 1281.
^{402g} Wahl and Le Bris, *Compt. rend.*, **235**, 1405 (1952).
^{402h} Wahl and Le Bris, *Compt. rend.*, **236**, 294 (1953).
⁴⁰²ⁱ Seyhan, *Chem. Ber.*, **88**, 212 (1955).
^{402j} Seiler and Schmid, *Helv. Chim. Acta*, **37**, 1 (1954).
^{402k} Ried and Gick, *Ann.*, **581**, 16 (1953).
⁴⁰³ Scott, O'Sullivan, and Reilly, *J. Chem. Soc.*, **1951**, 3508.
^{403a} Duffin and Kendall, *J. Chem. Soc.*, **1955**, 3470.
⁴⁰⁴ von Rothenburg, *J. prakt. Chem.*, [2], **51**, 43 (1895).
⁴⁰⁵ Knorr, *Ber.*, **29**, 249 (1896).
⁴⁰⁶ von Rothenburg, *Ber.*, **26**, 2972 (1893).
⁴⁰⁷ von Rothenburg, *Ber.*, **27**, 790 (1894).
⁴⁰⁸ von Rothenburg, *J. prakt. Chem.*, [2], **52**, 23 (1895).
⁴⁰⁹ von Rothenburg, *Ber.*, **27**, 783 (1894).
⁴¹⁰ Torrey and Zanetti, *Am. Chem. J.*, **44**, 391 (1910).
⁴¹¹ Graham, Porter, and Weissberger, *J. Am. Chem. Soc.*, **71**, 983 (1949).
⁴¹² Michaelis and Dorn, *Ann.*, **352**, 163 (1907).
⁴¹³ Knorr, *Ann.*, **238**, 183 (1887).
⁴¹⁴ Eibner, *Ber.*, **36**, 2687 (1903).
⁴¹⁵ Casoni, *Boll. sci. fac. chim. ind. Bologna*, **9**, 4 (1951) [*C. A.*, **45**, 7353 (1951)].

- ⁴¹⁶ Michaelis, *Ann.*, **338**, 183 (1905).
- ⁴¹⁷ Crippa, Long, and Perroneito, *Gazz. chim. ital.*, **62**, 944 (1932).
- ⁴¹⁸ Casoni, *Boll. sci. fac. chim. ind. Bologna*, **9**, 13 (1951) [*C. A.*, **45**, 7355 (1951)].
- ⁴¹⁹ Hayashi, Oshima, Tsuruoka, and Seo, *Rept. Japan Assoc. Advance. Sci.*, **17**, 47 (1942) [*C. A.*, **44**, 3258 (1950)].
- ⁴²⁰ Kohlbach, *Arch. Hem. Farm.*, **11**, 99 (1937) [*C. A.*, **33**, 2897 (1939)].
- ⁴²¹ Mackie and Cutler, *Rec. trav. chim.*, **71**, 1198 (1952).
- ⁴²² Knorr and Klotz, *Ber.*, **20**, 2545 (1887).
- ⁴²³ Vittum, Sawdey, Herdle, and Scholl, *J. Am. Chem. Soc.*, **72**, 1533 (1950).
- ⁴²⁴ Chattaway and Strouts, *J. Chem. Soc.*, **125**, 2423 (1924).
- ⁴²⁵ Michaelis and Willert, *Ann.*, **358**, 171 (1908).
- ⁴²⁶ Michaelis, *Ann.*, **373**, 129 (1910).
- ⁴²⁷ Michaelis, *Ann.*, **373**, 196 (1910).
- ⁴²⁸ Michaelis and Horn, *Ann.*, **373**, 213 (1910).
- ⁴²⁹ Sharvin, Arbuzov, and Varshavskii, *J. Chem. Ind. Moscow*, **6**, 1409 (1929) [*C. A.*, **25**, 501 (1931)].
- ⁴³⁰ Casoni, *Boll. sci. fac. chim. ind. Bologna*, **9**, 9 (1951) [*C. A.*, **45**, 7355 (1951)].
- ⁴³¹ Möllenhoff, *Ber.*, **25**, 1941 (1892).
- ⁴³² Ioffe and Khavin, *J. Gen. Chem. U.S.S.R.*, **17**, 522 (1947) [*C. A.*, **42**, 903 (1948)].
- ⁴³³ Hayashi, Hagiyaama, and Seo, *Rept. Japan Assoc. Advance. Sci.*, **17**, 253, 257 (1942) [*C. A.*, **44**, 3259 (1950)].
- ⁴³⁴ Darapsky, *J. prakt. Chem.*, [2], **67**, 175 (1903).
- ⁴³⁵ Efros and Davidenkov, *J. Gen. Chem. U.S.S.R.*, **21**, 2046 (1951) [*C. A.*, **46**, 8100 (1952)].
- ⁴³⁶ Michaelis and Brust, *Ann.*, **339**, 134 (1905).
- ⁴³⁷ Mohr, *J. prakt. Chem.*, [2], **79**, 1 (1909).
- ⁴³⁸ Michaelis and Klopstock, *Ann.*, **354**, 102 (1907).
- ⁴³⁹ Michaelis and Schäfer, *Ann.*, **397**, 119 (1913).
- ⁴⁴⁰ Michaelis and Klappert, *Ann.*, **397**, 149 (1913).
- ⁴⁴¹ Michaelis and Pander, *Ber.*, **37**, 2774 (1904).
- ⁴⁴² Michaelis and Pander, *Ann.*, **361**, 251 (1908).
- ⁴⁴³ Michaelis, *Ber.*, **38**, 154 (1905).
- ⁴⁴⁴ Michaelis and Behrens, *Ann.*, **338**, 228 (1905).
- ⁴⁴⁵ Michaelis, *Ann.*, **358**, 127 (1907).
- ⁴⁴⁶ Michaelis, *Ann.*, **373**, 209 (1910).
- ⁴⁴⁷ Michaelis and Burmeister, *Ber.*, **25**, 1502 (1892).
- ⁴⁴⁸ Michaelis and Simon, *Ann.*, **338**, 217 (1905).
- ⁴⁴⁹ Michaelis and Schenk, *Ber.*, **41**, 3865 (1908).
- ⁴⁵⁰ Asher, *Ber.*, **30**, 1018 (1897).
- ⁴⁵¹ Schiff, *Ber.*, **28**, 2731 (1895).
- ⁴⁵² Schiff and Viciani, *Ber.*, **30**, 1159 (1897).
- ⁴⁵³ Claisen and Zedel, *Ber.*, **24**, 140 (1891).
- ⁴⁵⁴ Posner and Schreiber, *Ber.*, **57**, 1127 (1924).
- ⁴⁵⁵ [Jensen and Pirnik], *J. Gen. Chem. U.S.S.R.*, **17**, 1828 (1947) [*C. A.*, **42**, 4171 (1948)].
- ⁴⁵⁶ Worrall, *J. Am. Chem. Soc.*, **44**, 1551 (1922).
- ⁴⁵⁷ Finger and Zeh, *J. prakt. Chem.*, [2], **82**, 50 (1910).
- ⁴⁵⁸ Curtius and Thompson, *Ber.*, **39**, 4140 (1906).
- ⁴⁵⁹ Dimroth, *Ann.*, **335**, 86 (1904).
- ⁴⁶⁰ Curtius and Callan, *Ber.*, **43**, 2447 (1910).
- ⁴⁶¹ Kuhlmg, *Ber.*, **31**, 1972 (1898).
- ⁴⁶² Whiteley, *J. Chem. Soc.*, **91**, 1330 (1907).
- ⁴⁶³ Whiteley and Mountain, *Chem. News*, **99**, 234 (1909).
- ⁴⁶⁴ Marschalk, *J. prakt. Chem.*, [2], **88**, 227 (1913).
- ⁴⁶⁵ Friedländer, *Monatsh.*, **30**, 347 (1909).
- ⁴⁶⁶ Auwers and Arndt, *Ann.*, **381**, 299 (1911).
- ⁴⁶⁷ Lesser and Schoeller, *Ber.*, **47**, 2292 (1914).

- ⁴⁶⁸ Stollé, Hecht, and Becker, *J. prakt. Chem.*, [2], **135**, 345 (1932).
⁴⁶⁹ Baeyer, *Ber.*, **16**, 2188 (1883).
⁴⁷⁰ Gabriel, *Ber.*, **20**, 1198 (1887).
⁴⁷¹ Pulvermacher, *Ber.*, **20**, 2492 (1887).
⁴⁷² Meyer and Vittenet, *Compt. rend.*, **192**, 885 (1931).
⁴⁷³ Meyer and Vittenet, *Compt. rend.*, **193**, 344 (1931).
⁴⁷⁴ Dieckmann, *Ber.*, **47**, 1428 (1914).
⁴⁷⁵ Huebner and Link, *J. Am. Chem. Soc.*, **67**, 99 (1945).
^{475a} Wiley and Ellert, *J. Am. Chem. Soc.*, **77**, 5187 (1955).
^{476a} Waldmann, *J. prakt. Chem.*, [2], **147**, 321 (1937).
^{476b} Malachowski and Kalinski, *Roczniki Chem.*, **6**, 768 (1926) [*C. A.*, **21**, 3615 (1927)].
^{476c} Malachowski, Giedroyc, and Jerzmanowska, *Ber.*, **61**, 2525 (1928).
^{476d} Huisgen and Koch, *Naturwiss.*, **41**, 16 (1954) [*C. A.*, **49**, 5344 (1955)].
⁴⁷⁷ McElvain and Jelinek, *J. Am. Chem. Soc.*, **65**, 2236 (1943).
⁴⁷⁸ Prager, *Ber.*, **34**, 3600 (1901).
⁴⁷⁹ Prager, *Ber.*, **36**, 1451 (1903).
⁴⁸⁰ Hinsberg, *J. prakt. Chem.*, [2], **85**, 337 (1912).

CHAPTER 2

THE JAPP-KLINGEMANN REACTION

ROBERT R. PHILLIPS

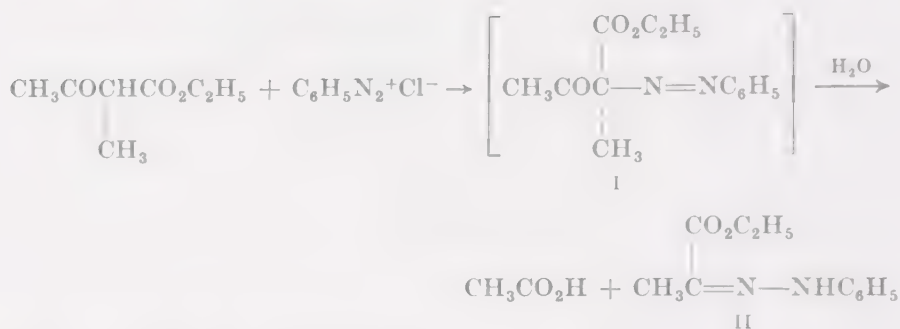
Eastman Kodak Company

CONTENTS

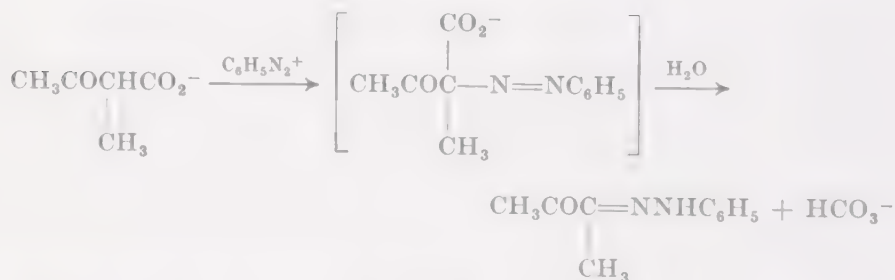
	PAGE
INTRODUCTION	144
MECHANISM	145
SCOPE AND APPLICATION	151
EXPERIMENTAL CONDITIONS	157
EXPERIMENTAL PROCEDURES	159
Ethyl Pyruvate <i>o</i> -Nitrophenylhydrazone.	159
1,2-Cyclohexanedione Monophenylhydrazone	159
TABULAR SURVEY OF THE JAPP-KLINGEMANN REACTION	159
A. Reactions in Which an Acyl Group Is Cleaved	161
Table I. Derivatives of Formylpropionic and Haloacetoacetic Acids	161
Table II. Monosubstituted Acetoacetic Esters	162
Table III. Acylacetoacetic Esters	166
Table IV. Acylecyanoacetic Esters	167
Table V. Cycle Compounds in Ring Opening Reactions	168
Table VI. 1,3-Dicarbonyl Compounds	170
Table VII. Miscellaneous Compounds	172
B. Reactions Accompanied by Decarboxylation	173
Table VIII. Acetoacetic Acid Derivatives	173
Table IX. Cyanoacetic Acid Derivatives	174
Table X. Malonic Acid Derivatives	174
Table XI. Miscellaneous Reactions	175

INTRODUCTION

In an attempt to prepare the azo ester I by coupling benzenediazonium chloride with ethyl 2-methylacetoacetate, Japp and Klingemann¹ obtained a product which was soon recognized¹⁻⁴ as the phenylhydrazone of ethyl pyruvate (II). It thus appeared that the acetyl group had been dis-



placed; actually the coupling product I was unstable under the conditions of its formation, undergoing hydrolytic scission of the acetyl group and rearrangement of the azo structure. A year later the same authors discovered that, if the substituted acetoacetic ester was saponified and the coupling carried out on the sodium salt, the carboxylate function, rather than the acetyl group, was lost and the product isolated was the phenylhydrazone of biacetyl.^{4,5}



In later years the reaction has been extended to other systems containing activated methinyl groups. The process can be generalized as shown in the following equation, in which x and y are electron-withdrawing groups.

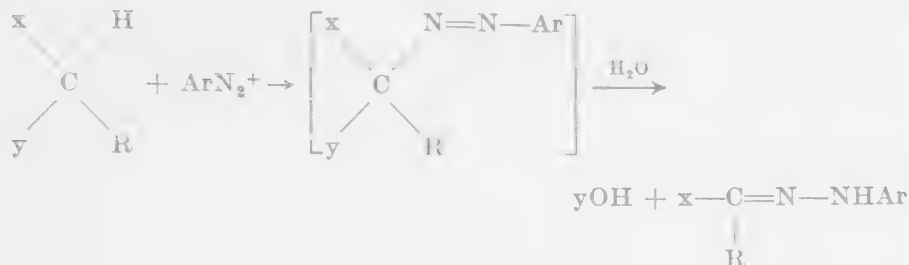
¹ Japp and Klingemann, *Ber.*, **20**, 2942 (1887).

² Japp and Klingemann, *Ber.*, **20**, 3284 (1887).

³ Japp and Klingemann, *Ber.*, **20**, 3398 (1887).

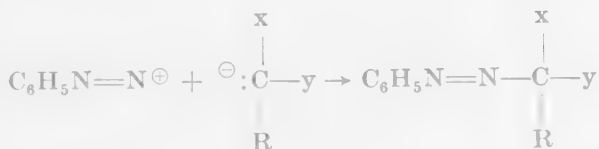
⁴ Japp and Klingemann, *Ber.*, **21**, 549 (1888).

⁵ Japp and Klingemann, *Ann.*, **247**, 190 (1888); *J. Chem. Soc.*, **53**, 519 (1888).



MECHANISM

As is apparent from the above equations the Japp-Klingemann reaction is a special case of the coupling of diazonium salts with aliphatic compounds (see Chapter 1), distinguished by the fact that the coupling product ordinarily undergoes solvolysis as rapidly, or almost as rapidly, as it is formed. It resembles very closely the nitrosation and cleavage of active methinyl compounds discussed in an earlier volume of this series.⁶ The first step undoubtedly occurs by the same mechanism as the similar coupling with an active methylene compound (for a discussion see p. 6), and is probably best represented as a direct union of the anion of the active methinyl compound and the diazonium cation, which are shown in the accompanying equation as the forms carrying full unit charges on the atoms that unite in the process.



Much of the early concern⁷⁻⁹ about the mechanism of such couplings dealt with the question of the participation of the enolic forms of the active methinyl compounds and with the status of O-azo compounds as possible intermediates (p. 4). Although the mechanism just shown is probably an accurate representation of the coupling of mono- β -keto esters, there can be little doubt but that O-azo compounds are sometimes first formed from di- β -keto esters and triketones. Thus tribenzoylmethoxine yields a coupling product that generates an azo dye upon treatment with *β*-naphthol and undoubtedly is the derivative of the enol.¹⁰

⁶ Touster, in Adams, *Organic Reactions*, Vol. 7, Chapter 6, John Wiley & Sons, 1953.

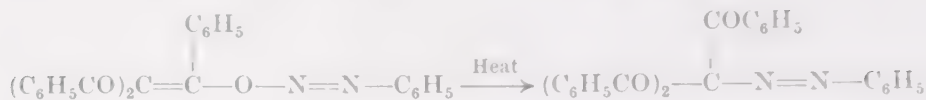
⁷ Dimroth and Hartmann, *Ber.*, **41**, 4012 (1908).

⁸ Dimroth, *Ber.*, **40**, 2404 (1907).

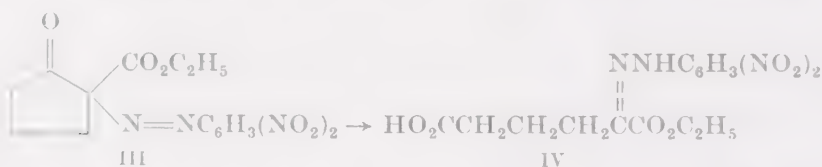
⁹ Dimroth and Hartmann, *Ber.*, **40**, 4460 (1907).

¹⁰ Dimroth, Leichtlin, and Friedemann, *Ber.*, **50**, 1534 (1917).

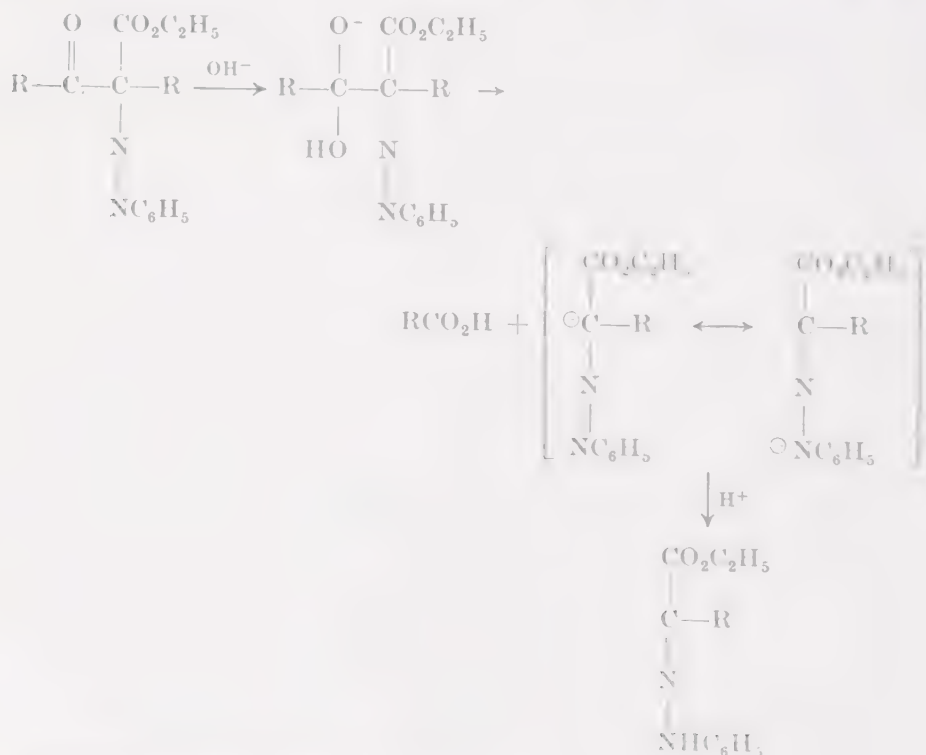
When it is heated to its melting point it changes to an isomer that does not have this property and must be the C-azo compound.



The cleavage step is closely similar to the scission of triacylmethanes and of nitroso derivatives of monosubstituted active methylene compounds.⁷ The cleavage is favored by increasing alkalinity of the solution; for example the azo compound III can be obtained from the diazonium salt prepared from 2,4-dinitroaniline and ethyl cyclopentanone-2-carboxylate by coupling in acetic acid solution, but it is rapidly cleaved by aqueous base, yielding IV.¹¹ In analogy with the base-catalyzed



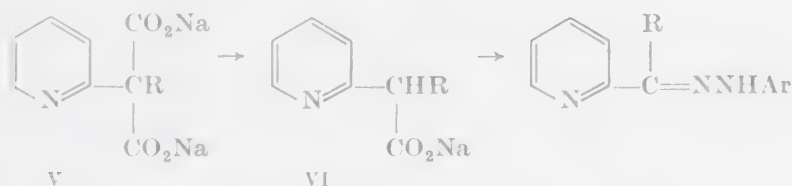
cleavage of nitroso esters⁹ the second step of the Japp-Klingemann reaction can be represented as shown. In the decomposition of the



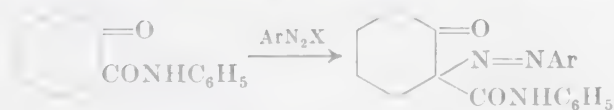
¹¹ Einstead and Wang, *J. Chem. Soc.*, 1937, 807.

product obtained by coupling with a salt of a keto acid, the resonating anion which gives rise to the phenylhydrazone probably results from the loss of carbon dioxide from the carboxylate anion.

Support for the above interpretation of the Japp-Klingemann process can be found in the isolation of many intermediate azo compounds,^{7,11-14} although not all attempts to obtain these intermediates have been successful.¹⁴ That the coupling with salts of β -keto acids and malonic acids does not proceed by a direct displacement of the carboxyl group is indicated by the observation that malonate salts of the type V react much more slowly than their decarboxylation products VI.¹⁵ Thus it appears likely that the malonate salt V undergoes decarboxylation before it reacts with the diazonium salt.

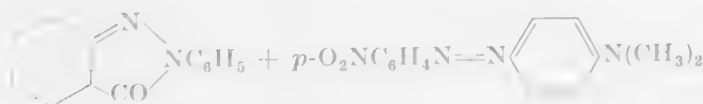
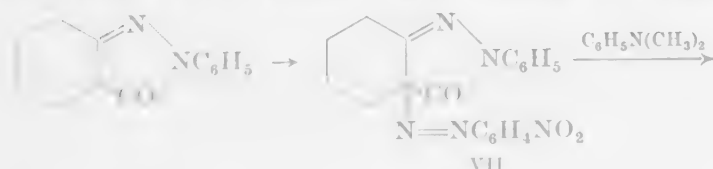


Azo derivatives of cyclohexanone-2-carboxamide are relatively stable and can be isolated from coupling reactions of the anilide.¹¹ However,



some of the monoaryldiazo compound of cyclohexanone-2-carboxamide was formed along with the azoanilide, presumably as a result of hydrolysis followed by decarboxylation.

The phenylpyrazolone obtained from ethyl cyclohexanone-2-carboxylate couples with diazotized *p*-nitroaniline to give the unusually interesting azo derivative VII. Although quite unstable, VII does not undergo the



⁷ Favrel, *Bull. soc. chim. France*, [4], **47**, 1290 (1930).

¹¹ Favrel, *Compt. rend.*, **189**, 335 (1927).

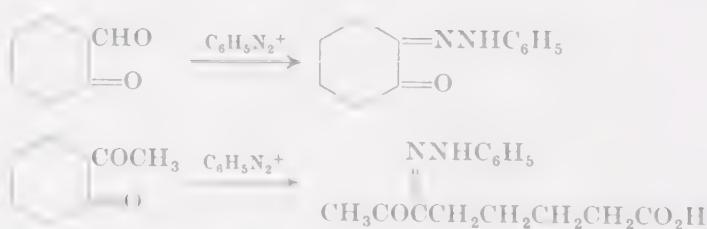
¹² Kalb, Schweitzer, Zellner, and Berthold, *Ber.*, **59**, 1860 (1926).

¹⁵ Frank and Phillips, *J. Am. Chem. Soc.*, **71**, 2804 (1949).

Japp-Klingemann transformation, but instead loses the azo function in a reversal of the coupling reaction. Thus it reacts as shown with dimethylaniline, similarly, it reacts with ethanol to regenerate the original pyrazolone and to form nitrobenzene, acetaldehyde, and nitrogen.¹⁴

Most of the compounds that have been subjected to the Japp-Klingemann reaction can be classified as substituted β -diketones, β -keto esters (acyclic or cyclic), cyanoacetic esters, or salts of the corresponding acids. The cleavage of the coupling products apparently represents a special case of the cleavage of diketones, β -keto esters, and similar compounds. Nearly all of the recorded examples of the reaction concern derivatives of β -keto esters; as indicated above, in the scission of these substances an aliphatic acyl group is much more labile than a carbalkoxyl group, but, if the carbalkoxyl group is first saponified, then the carboxylate ion is eliminated in preference to the acyl group.

Although no direct comparison of a formyl group and an acetyl group in a Japp-Klingemann cleavage appears to have been made, the formyl group would be expected to be the more labile. Ethyl formylpropionate¹⁵ undergoes the reaction with the fission of the formyl group, as expected, and certain formyl derivatives of cyclanones, such as 2-formyleyclohexanone,¹⁷ undergo the reaction with loss of the formyl group under conditions which bring about ring opening (the alternative scission) with the corresponding acetyl derivatives.



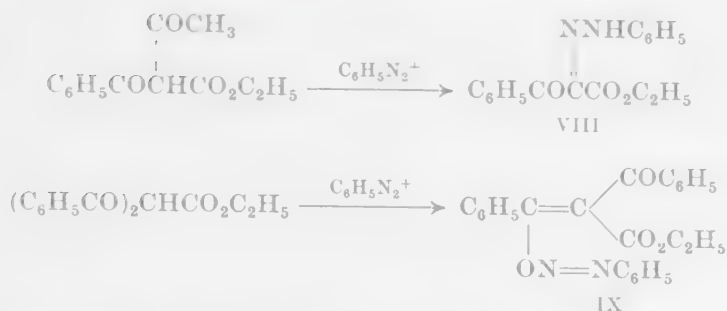
Little is known about the cleavage of aromatic acyl groups, but they appear to be much more firmly bound than their aliphatic analogs. *z,z*-Dibenzoylacetone undergoes the reaction with loss of the acetyl group.¹⁶ Ethyl dibenzoylacetate⁹ reacts with diazotized aniline in a



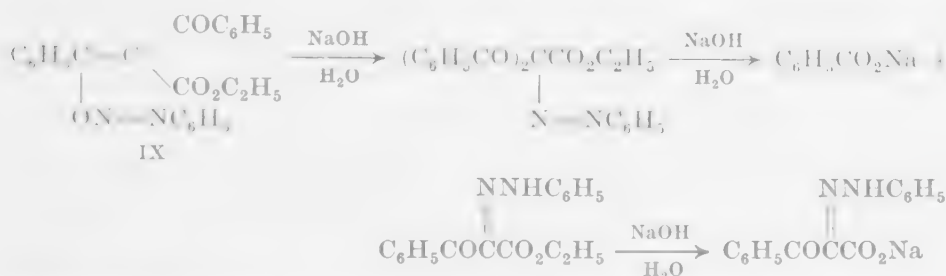
buffered solution (sodium acetate) to give the oxygen-azo compound IX under conditions which cause the cleavage of the coupling product VIII

¹⁴ Michael, *Ber.*, **38**, 2096 (1905).

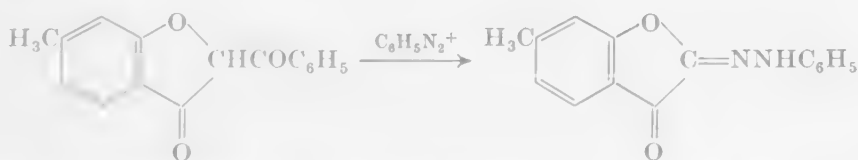
¹⁷ Coffey, *Rec. trav. chim.*, **42**, 528 (1923); Sen and Ghosh, *J. Indian Chem. Soc.*, **4**, 477 (1927).



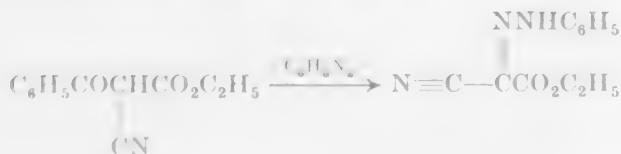
from ethyl benzoylacetate.¹⁸ Warm dilute alkali brings about the cleavage of IX, and, since benzoic acid is eliminated, it is probable that rearrangement and scission precede hydrolysis; the product isolated is the acid corresponding to the salt shown.⁹



Nevertheless, there are examples of the facile cleavage of a benzoyl group. For example, von Auwers and Pohl¹⁹ used the Japp-Klingemann reaction to prepare a derivative of 2-benzoyl-6-methylcoumaran-3-one. It is especially interesting that the cleavage of the benzoyl group occurred in preference to ring opening.



The benzoyl group is eliminated in preference to a cyano group. Thus ethyl benzoylcyanoacetate leads to a derivative of mesoxalic acid.^{20,21}



¹⁸ Bülow and Haier, *Ber.*, **35**, 915 (1902).

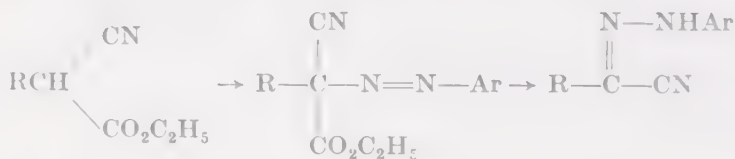
¹⁹ von Auwers and Pohl, *Ann.*, **405**, 243 (1914).

²⁰ Favrel, *Bull. soc. chim. France*, [3], **27**, 200 (1902).

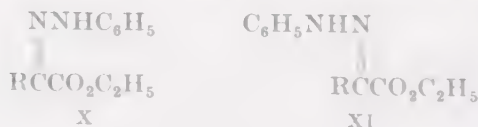
²¹ Favrel, *Compt. rend.*, **131**, 190 (1900).

Bulow and Hailer applied the Japp-Klingemann reaction to the ethyl esters of several diacylacetic acids.¹⁸ From ethyl propionylacetoacetate they isolated the phenylhydrazone corresponding to cleavage of the propionyl group. The product from ethyl benzoylacetoacetate contained the benzoyl group (loss of acetyl) and that from ethyl phenacetylacetoacetate contained the phenacetyl group (loss of acetyl). It was concluded that in such cleavages the acyl group corresponding to the weaker acid is liberated the more readily (the corrected acidity constants,²² $10^6 K_a$, of the acids concerned are: propionic acid, 1.33; acetic acid, 1.75; phenylacetic acid, 4.88; benzoic acid, 6.27). In a study of the cleavage of unsymmetrical 1,3-diketones of the type $\text{RCOCH}_2\text{COR}'$, Hauser, Swamer, and Ringler²³ found a correlation of the relative yields of the acids RCO_2H and $\text{R}'\text{CO}_2\text{H}$ with the rates of saponification of the ethyl esters of these acids although the relationship did not hold well with purely aliphatic compounds. On this basis the acetyl group would be expected, contrary to observation, to undergo cleavage in either ethyl benzoylacetoacetate or ethyl propionylacetoacetate (the rate constants, $10^4 k$, for the alkaline hydrolysis of the ethyl esters of the acids are:²⁴ $\text{C}_6\text{H}_5\text{CO}_2\text{C}_2\text{H}_5$, 5.50; $\text{CH}_3\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$, 35.5; $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$, 69.5).

In the cleavage of substituted cyanoacetic esters during the second stage of the Japp-Klingemann reaction, saponification and decarboxylation invariably occur leading to the phenylhydrazones of α -ketonitriles. Apparently no instance of the scission of the nitrile group has been recorded.



Perhaps one reason why more precise information is lacking on the direction of cleavage of azodiketones in the Japp-Klingemann reaction is that the arylhydrazones produced in the process usually are capable of existing in geometrically isomeric forms (e.g., X and XI). Both isomers often are produced, and it may be economical to subject the crude



²² Ingold, *Structure and Mechanism in Organic Chemistry*, p. 734, Cornell University Press, Ithaca, N. Y., 1953.

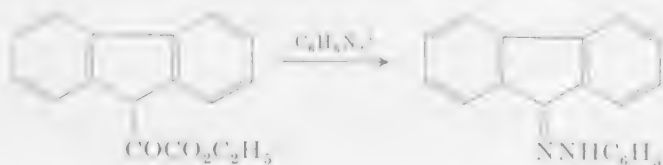
²³ Hauser, Swamer, and Ringler, *J. Am. Chem. Soc.*, **70**, 4023 (1948).

²⁴ Hammett, *Physical Organic Chemistry*, p. 121, McGraw-Hill Book Co., New York, 1940.

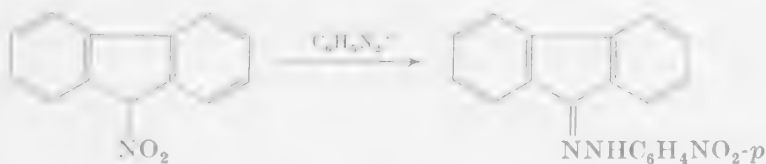
material to the next reaction in a sequence, with purification at a later stage, rather than to isolate the pure arylhydrazone. As a result, yields of the arylhydrazones often are not reported.

SCOPE AND APPLICATION

The first requirement for the occurrence of the Japp-Klingemann reaction is the presence of a hydrogen atom of sufficient activity to permit the coupling with the diazonium salt. Although normally two or three electron-withdrawing groups, such as carbonyl, carboxyl, cyano, etc., are present in the molecule, only one such group is required if other labilizing influences are operative upon the hydrogen atom concerned. For example, 9-ethoxalylfluorene reacts in the typical fashion.²⁵ A



particularly interesting reaction is that of 9-nitrofluorene;²⁶ in the coupling with diazotized aniline the displaced nitro group appears in the para position of the phenylhydrazone residue of the product.



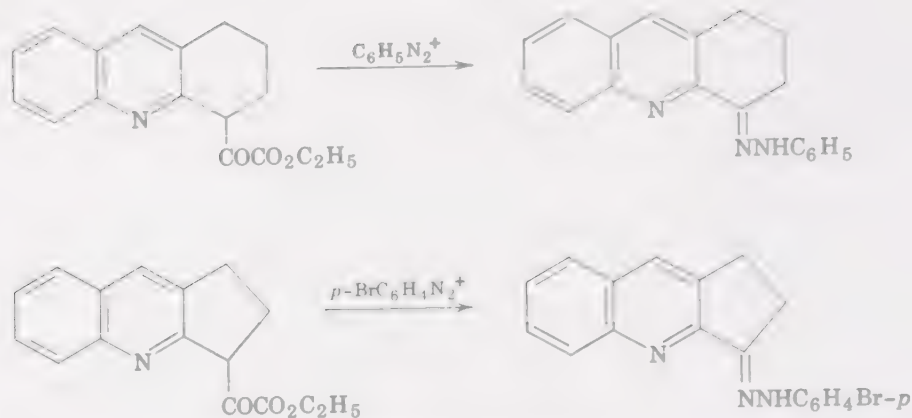
A methinyl group in the α -position of a pyridine compound also is reactive enough to participate in the Japp-Klingemann process if one additional activating group is present. For example, 2-*n*-butyrylpyridine has been prepared in good yield from 2-(2'-pyridyl)pentanoic acid by the process shown.²⁵ A somewhat similar reaction is that of 1-ethoxalyl-1,2,3,4-tetrahydroacridine and the analogous cyclopenteno derivative.²⁷



²⁵ Kuhn and Levy, *Ber.*, **61**, 2240 (1928).

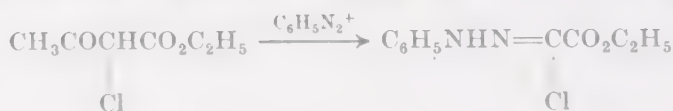
²⁶ Ponzio, *Gazz. chim. ital.*, **42**, [II], 55 (1912).

²⁷ Borschi and Mantovelli, *Ann.*, **534**, 56 (1938).

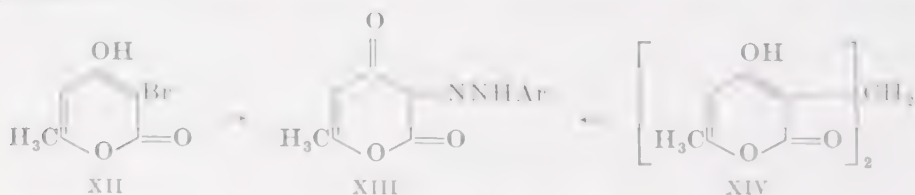


In contrast with 9-nitrofluorene, α -nitropropionic acid retains the nitro group in the reaction. Decarboxylation takes place to yield the phenylhydrazone, $\text{CH}_3\text{C}(\text{NO}_2)=\text{NNHC}_6\text{H}_5$, identical with the product obtained from nitroethane and benzenediazonium chloride.²⁸

Esters of a great variety of monosubstituted acetoacetic acids have been subjected to the reaction. Chlorine and bromine atoms may serve as the third substituent on the methinyl carbon. These halogen atoms are not removed during the reaction but appear in the products, which are phenylhydrazones of unusual structure, as shown in the equation.^{29,30}



One exception to the statement that halogen is not removed is the coupling of 3-bromotriacetic lactone (XII), which furnishes the same arylhydrazone XIII as that obtained from triacetic lactone itself.^{30a} Methylene bis(triacetic lactone) (XIV) on coupling also yields the arylhydrazone XIII.



Alkylsubstituted acetoacetic esters are more commonly encountered. The products from such esters are readily reduced and hydrolyzed, and

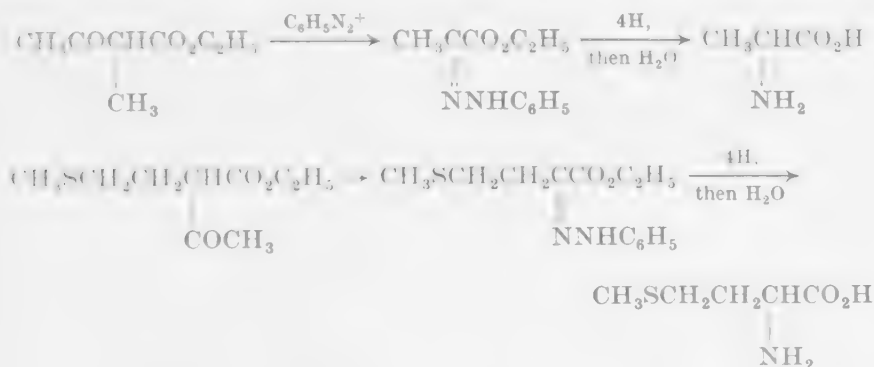
²⁸ Steinkopf and Supan, *Ber.*, **43**, 3239 (1910).

²⁹ Favrel, *Compt. rend.*, **134**, 1312 (1902).

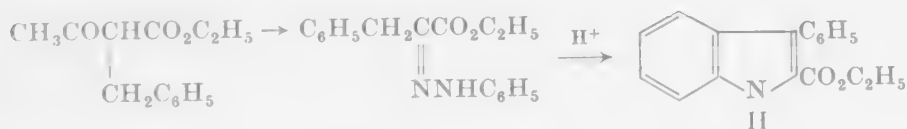
³⁰ Favrel, *Bull. soc. chim. France*, [3], **31**, 150 (1904).

^{30a} Wiley and Jarboe, *J. Am. Chem. Soc.*, **78**, 624 (1956).

this method of synthesis of α -amino acids has been employed extensively. Examples are the syntheses of alanine³¹⁻³⁴ and methionine.³⁵



The phenylhydrazones from the Japp-Klingemann reaction on simply substituted acetoacetic esters also have been used extensively in the synthesis of indoles. The Fischer cyclization converts them to esters of substituted indole-2-carboxylic acids. The preparation of ethyl 3-phenylindole-2-carboxylate is illustrative.³⁶



Substituents in the benzene ring of the indole may be introduced through the use of a substituted benzenediazonium salt in the coupling. Diazonium salts from 2- and 4-substituted anilines can give only one product in a simple Fischer cyclization, but two different indoles may be obtained from a *m*-substituted aniline,³⁷ and consequently these have been employed infrequently. Examples of the products obtained from 2- and 4-substituted anilines are shown.^{38,39}

³¹ Fieser and Glick, *Compt. rend. acad. sci. U.R.S.S.*, **24**, 755 (1939) [*C. A.*, **34**, 1971 (1940)].

³² Fieser and Glick, and others, *Bull. acad. sci. U.R.S.S. Classe sci. chim.*, **1940**, 259 [*C. A.*, **35**, 3606 (1941)].

³³ Bamberger, *Ber.*, **25**, 3547 (1892).

³⁴ Froilantov and Zaitseva, *J. Gen. Chem. U.S.S.R.*, **10**, 258 (1940) [*C. A.*, **34**, 7283 (1940)].

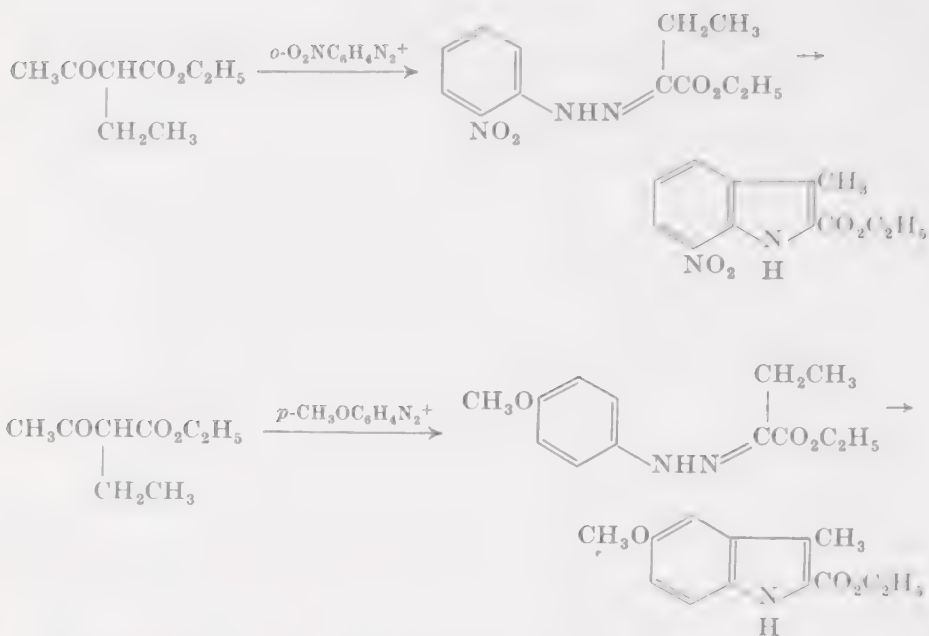
³⁵ Frofilaktov and Ivanova, *J. Gen. Chem. U.S.S.R.*, **21**, 1684 (1951) [*C. A.*, **46**, 3955 (1952)].

³⁶ Manske, Perkin, and Robinson, *J. Chem. Soc.*, **1927**, 1.

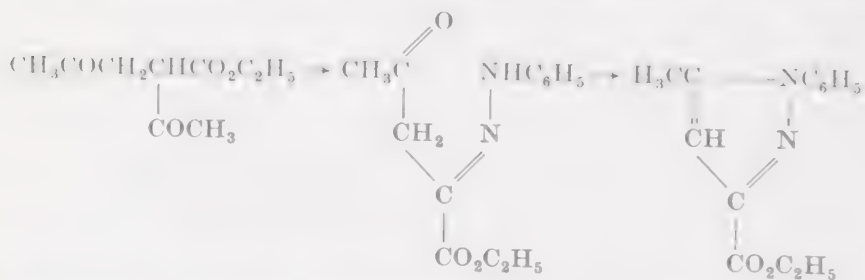
³⁷ Koelsch, *J. Org. Chem.*, **8**, 295 (1943).

³⁸ Hulse, Linn, and Richter, *J. Proc. Roy. Soc. N. S. Wales*, **72**, 209 (1938) [*C. A.*, **33**, 6837 (1939)].

³⁹ Hulse and Linn, *J. Proc. Roy. Soc. N. S. Wales*, **71**, 476 (1937) [*C. A.*, **33**, 587 (1939)].

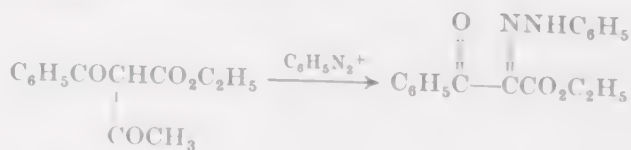


If the substituent in the acetoacetic ester has a carbonyl group attached to the first carbon atom, the phenylhydrazone from the Japp-Klingemann reaction will readily cyclize to a pyrazole. Acetonyl⁴⁰ and phenacyl⁴¹



groups, which may bear additional substituents, have been employed in this way.

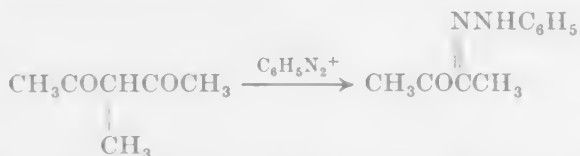
Acyl derivatives of acetoacetic ester also may be employed. The products are monophenylhydrazones of α,β -diketo esters. Thus ethyl benzoylacetate reacts as shown.¹⁸



⁴⁰ Bischler, *Ber.*, **26**, 1881 (1893).

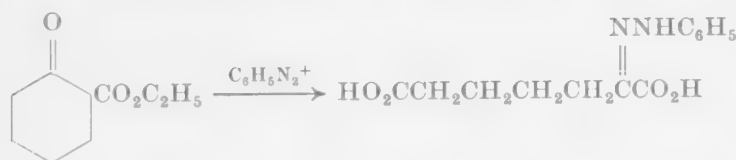
⁴¹ Bischler, *Ber.*, **25**, 3143 (1892).

Probably because they have been less readily available than acetoacetic esters, 1,3-diketones have not been extensively employed in the Japp-Klingemann reaction. Among those which have been examined are α -chloro,⁴² α -methyl,⁴³ and α -ethyl-acetylacetone.⁴³ The products are monophenylhydrazones of 1,2-diketones, as illustrated for the methyl derivative. The same products are available from the substituted β -keto

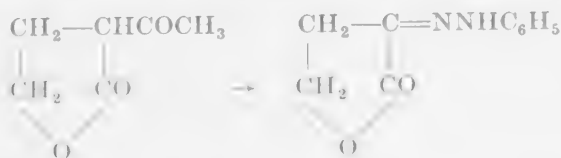


esters, provided the ester group is saponified before the coupling is performed (p. 144). Such monophenylhydrazones have been prepared from several substituted acetoacetic esters.

When the Japp-Klingemann reaction is applied to a cyclic β -keto ester, the ring is opened in the second stage of the process. The reaction of ethyl cyclohexanone-2-carboxylate is illustrative.^{11,44} Cyclopentanone



derivatives undergo similar ring opening. The products from both series have been employed in the synthesis of amino acids and indoles. The ring opened may be that of a lactone, as in acetobutyrolactone, which yields the phenylhydrazone of ketobutyrolactone.⁴⁵ This product also



has found use in the synthesis of amino acids.^{46,47} Alternatively the ring opened may be that of a lactam, as in the elegant synthesis of tryptamine

⁴² Dieckmann and Platz, *Ber.*, **38**, 2986 (1905).

⁴³ Favrel, *Bull. soc. chim. France*, [3], **27**, 336 (1902); *Compt. rend.*, **132**, 41 (1901).

⁴⁴ Feofilaktov and Ivanov, *J. Gen. Chem. U.S.S.R.*, **13**, 457 (1943) [*C. A.*, **38**, 3255 (1944)].

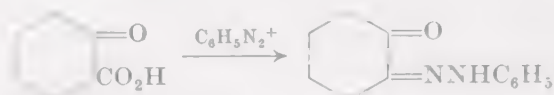
⁴⁵ Harradence and Lions, *J. Proc. Roy. Soc. N. S. Wales*, **72**, 221 (1938) [*C. A.*, **33**, 6838 (1939)].

⁴⁶ Feofilaktov and Onishchenko, *J. Gen. Chem. U.S.S.R.*, **9**, 314 (1939) [*C. A.*, **34**, 378 (1940)].

⁴⁷ Snyder, Andreen, Cannon, and Peters, *J. Am. Chem. Soc.*, **64**, 2082 (1942).

and serotonin (5-hydroxytryptamine) based on the coupling with a salt of α -carboxy- α -valerolactone and a Fischer cyclization of the products.¹⁰

As in the reactions of acyclic β -keto esters, the reaction takes the decarboxylation course if the ester is saponified before the coupling. Thus a monophenylhydrazone of cyclohexane-1,2-dione is obtained from ethyl cyclohexanone-2-carboxylate.¹¹

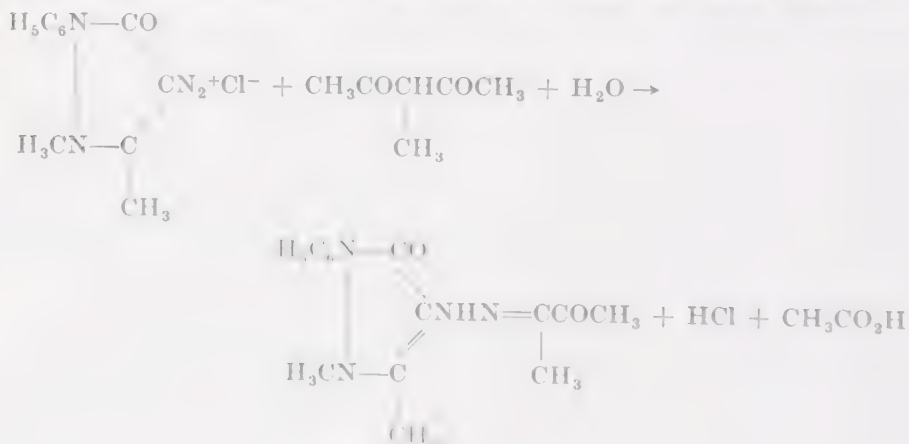


Such compounds may serve as sources of derivatives of α -aldehyde acids. When the *o*-nitrophenylhydrazone obtained from cyclopentanone-2-carboxylic acid was allowed to stand in aqueous alcoholic potassium hydroxide for five days it was converted to the *o*-nitrophenylhydrazone of δ -formylbutyric acid in about 35% yield.¹¹



Monosubstituted cyanoacetic esters couple readily. When the products are hydrolyzed, decarboxylation ensues leading to hydrazones of α -keto nitriles. Substituted malonic esters yield phenylhydrazones of α -keto acids, identical to those which can be obtained from similarly substituted acetoacetic esters.

The diazonium salts used in the reaction include those derived from aniline and its simple substitution products, polysubstituted anilines, benzidine and substituted benzidines, and even antipyrine. The diazonium salt related to the last substance has been coupled with 3-methylpentane-2,4-dione¹² to give the hydrazone shown in the equation.



^{10a} Abramovitch and Shapiro, *Chemistry & Industry*, **1955**, 1255.

¹² Morgan and Reilly, *J. Chem. Soc.*, **103**, 808 (1913).

It might be expected that diazonium salts in which electron-withdrawing groups are located in ortho or para positions, so that they accentuate the positive character of the diazonium cation, would be most active in the coupling. In couplings with 2-pyridylacetic acid, diazotized *p*-aminobenzoic acid gave the best results, and diazotized *p*-nitroaniline and sulfamic acid were superior, both with regard to the yield and the purity of the products, to diazotized aniline.⁴⁵ Although few experiments have been carried out with a single active methinyl compound and a variety of diazonium salts in the Japp-Klingemann reaction under identical conditions, the yields from substituted anilines appear to run higher than those from aniline. It is possible that substituents such as the nitro and carboxyl groups may give rise to higher melting and less soluble products, leading to easier isolation as well as to more complete reaction.

If the arylamino portion of a Japp-Klingemann product is to be removed, as in a reduction to an α -amino acid (pp. 152-153), the diazonium salt should be selected not only on the basis of the probable yield in the coupling but also with consideration of the character of the second product in the further reaction. For example, if a diazotized aminobenzoic acid were used in a coupling carried out as part of a sequence to an α -amino acid, the difficulty of separating this product from the regenerated aminobenzoic acid might outweigh any advantage gained in the coupling.

In the preparation of arylhydrazones to be employed in the synthesis of indoles and pyrazoles the choice of the diazonium salt is dictated by the substituents desired in the final product.

EXPERIMENTAL CONDITIONS

Most of the reactions have been run in aqueous medium at about 0°. Occasionally ethanol has been added to increase the solubility.⁴⁹ In the coupling of 1-ethoxycetyl-1,2,3,4-tetrahydroacridine (p. 151) the medium was pyridine diluted with the water in which the diazonium salt was prepared.⁵⁰ The aqueous solutions usually are buffered with sodium acetate in reactions in which an acyl group is to be cleaved.^{20,50} Stronger bases have been used, however. In the conversion of ethyl cyclopentanone-2-carboxylate to the phenylhydrazone of ethyl hydrogen α keto-adipate, Manske and Robinson⁵¹ employed potassium hydroxide; for the preparation of the similar product from diazotized *m*-aminobenzoic acid,

⁴⁹ Lions and Spruson, *J. Proc. Roy. Soc. N. S. Wales*, **66**, 171 (1932) [*C. A.*, **27**, 291 (1933)].

⁵⁰ Favrel and Chrz., *Bull. soc. chim. France*, [4], **37**, 1238 (1925).

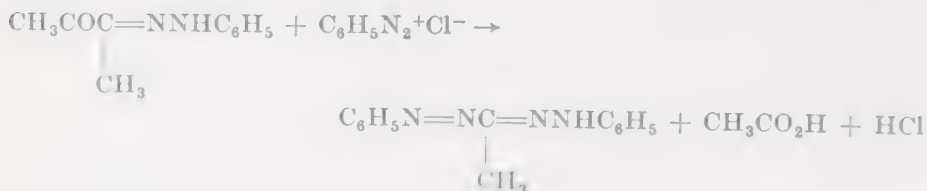
⁵¹ Manske and Robinson, *J. Chem. Soc.*, **1927**, 240.

Koelsch³⁷ preferred to carry out the coupling in acid solution and to convert the azo compound so obtained to the substituted hydrazone by a two-minute treatment with boiling 7% aqueous sodium carbonate. Other couplings also have been found to occur under either acid or basic conditions,^{8,43,52} and even sodium ethoxide has been used as the base.⁵³

If the cleavage of the acyl group from a β -keto ester is desired, the basic solution of the ester should be treated with the diazonium salt immediately.⁵⁴ If such basic solutions are allowed to stand at 0° for periods up to twenty-four hours before the treatment with the diazonium salt, the ester group is removed and the product obtained is a derivative of a 1,2-diketone.^{11,55,56}

The time required for the Japp-Klingemann process varies, with the activity of the methinyl group, from a few seconds to as much as four days.¹⁵ When aqueous solutions are employed the products often separate, and the mixture can be stirred until no further change occurs. The azo compounds, sometimes encountered as intermediates (p. 147), are much more deeply colored (usually red) than the arylhydrazones. Accordingly, a color change sometimes furnishes a useful guide to the course of the reaction.

Most of the reactions have been run with equivalent amounts of the methinyl component and the diazonium salt. The use of excess diazonium salt may result in the loss of some of the product by conversion to the formazyl, as shown in the equation.^{33,57} This appears to be the only



serious side reaction in the Japp-Klingemann process, aside from the alternative cleavage of keto esters (above). Another disadvantage to the use of an excess of the diazonium salt is the formation of colored materials and tars as a result of its decomposition when the reaction mixture is allowed to warm.

The products from the Japp-Klingemann reaction usually have been

⁵² Findlay and Dougherty, *J. Org. Chem.*, **13**, 560 (1948).

⁵³ Feofilaktov, *J. Gen. Chem. U.S.S.R.*, **17**, 993 (1947) [*C. A.*, **42**, 4537 (1948)].

⁵⁴ Jackson and Manske, *J. Am. Chem. Soc.*, **52**, 5029 (1930).

⁵⁵ Manske, *Can. J. Research*, **4**, 591 (1931).

⁵⁶ Lions, *J. Proc. Roy. Soc. N. S. Wales*, **66**, 516 (1932) [*C. A.*, **27**, 2954 (1933)].

⁵⁷ Walker, *J. Chem. Soc.*, **123**, 2775 (1923).

recrystallized from ethanol or benzene: 80% acetic acid has been employed in some instances.⁵⁸

EXPERIMENTAL PROCEDURES

Ethyl Pyruvate *o*-Nitrophenylhydrazone.⁵⁸ To an ice-cold solution of 20.5 g. (0.14 mole) of ethyl 2-methylacetoacetate in 150 ml. of ethanol is added 51 ml. of 50% aqueous potassium hydroxide. This mixture is then diluted with 300 ml. of ice water; and the cold diazonium salt solution, prepared from 20.0 g. (0.14 mole) of *o*-nitroaniline, 60 ml. of concentrated hydrochloric acid, 90 ml. of water, and 10.5 g. of sodium nitrite, is rapidly run in with stirring. Stirring is continued for five minutes, at the end of which time the separated ethyl pyruvate *o*-nitrophenylhydrazone is collected by filtration. It melts at 106°, after recrystallization from ethanol. The yield is 30.0 g. (83%).

1,2-Cyclohexanedione Monophenylhydrazone.⁵⁶ To an ice-cold solution of 36.0 g. (0.21 mole) of ethyl cyclohexanone-2-carboxylate in 40 ml. of ethanol is added an ice-cold solution of 12.0 g. of potassium hydroxide in 60 ml. of water. The reaction mixture is held at 0° for twenty-four hours and then diluted with 1 l. of ice water. A benzene-diazonium chloride solution is prepared from 18.6 g. (0.2 mole) of aniline, 50 ml. of concentrated hydrochloric acid in 100 ml. of water, and 13.8 g. of sodium nitrite. The cold diazonium solution is then added to the first solution with vigorous stirring and continued cooling in ice, followed immediately by the addition of 30.0 g. of sodium acetate. Carbon dioxide is seen to evolve, and the reaction is allowed to continue at 0° until the gas evolution ceases. The solid product which separates is 1,2-cyclohexanedione monophenylhydrazone. It is collected by filtration and recrystallized from ethanol. It melts at 185-186°. The yield is almost quantitative.

TABULAR SURVEY OF THE JAPP-KLINGEMANN REACTION

The following list of Japp-Klingemann reactions includes many examples in which the products were further modified, so that yields are not available. The list is based on a literature survey to January 1, 1956, but because of the difficulties of locating scattered instances of the reaction in the literature, especially when the products are chiefly of interest as intermediates in further reactions, it probably does not include

⁵⁸ Feofilaktov and Vinogradova, *Compt. rend. acad. sci. U.R.S.S.*, **24**, 759 (1939) [*C. A.*, **34**, 1971 (1940)].

all recorded applications of the Japp-Klingemann reaction. For convenience the reactions in which an acyl group is cleaved are listed separately (section A) from those accompanied by decarboxylation (section B). Accordingly, some compounds will be found in both sections. Section A is subdivided as follows:

I. Derivatives of nitropropionic, formylpropionic, and haloacetoacetic acids.

II. Monosubstituted acetoacetic esters.

III. Acylacetoacetic esters.

IV. Acylcyanoacetic esters.

V. Cyclic compounds.

VI. 1,3-Dicarbonyl compounds.

VII. Miscellaneous compounds.

Section B is subdivided as follows:

VIII. Acetoacetic acid derivatives.

IX. Cyanoacetic acid derivatives.

X. Malonic acid derivatives.

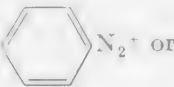
XI. Miscellaneous reactions.

A. Reactions in Which an Acyl Group Is Cleaved

TABLE I

DERIVATIVES OF FORMYLPROPIONIC AND HALOACETOACETIC ACIDS

(The group lost in the cleavage is italic.)

Substance	Substituent in  or [Other Diazonium Ion]	Yield, %	References	Conversion Product
$\text{CH}_3\text{CHCO}_2\text{C}_2\text{H}_5$	—	—	16	—
$\begin{array}{c} \text{CHO} \\ \\ \text{CH}_3\text{COCHCO}_2\text{CH}_3 \end{array}$	—	—	30	—
$\begin{array}{c} \\ \text{Cl} \end{array}$	—	—	59	—
	2-CH ₃	—	30	—
	4-CH ₃	—	30	—
$\text{CH}_3\text{COCHCO}_2\text{C}_2\text{H}_5$	—	—	29, 30	—
$\begin{array}{c} \\ \text{Cl} \end{array}$	—*	—	59	—
	2-CH ₃	—	29, 30	—
	4-CH ₃ *	—	29, 30	—
	4-Br*	—	60	—
	[Certain benzidine derivatives]	—	30	—
$\text{CH}_3\text{COCHCONHC}_6\text{H}_5$	4-CH ₃	80	61	—
$\begin{array}{c} \\ \text{Cl} \end{array}$	3-CH ₃ , 4-CH ₃	—	61	—
	3-CH ₃ , 5-CH ₃	—	61	—
	[$\alpha\text{-C}_{10}\text{H}_7\text{N}_2^+$]	—	61	—
	[$\beta\text{-C}_{10}\text{H}_7\text{N}_2^+$]	—	61	—
$\text{CH}_3\text{COCHCO}_2\text{C}_{10}\text{H}_{19}\dagger\dagger$	—	—	62	—
$\begin{array}{c} \\ \text{Br} \end{array}$	4-Br	—	62	—
	4-CH ₃	—	62	—

Note: References 59–118 are on pp. 177–178.


* These reagents have also been coupled with ethyl α -bromoacetoacetate, ref. 60.

† The (–)-menthyl ester.

* Certain reactions of the ethyl ester are entered under ethyl α -chloroacetoacetate.

TABLE II—Continued

MONOSUBSTITUTED ACETOACETIC ESTERS IN THE REACTION:



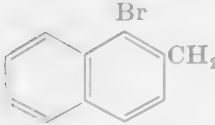
$\text{CH}_3\text{COCH}(\text{R})\text{CO}_2\text{C}_2\text{H}_5 + \text{ArN}_2^+\text{X}^- \rightarrow [\text{CH}_3\text{CO}(\text{C}(\text{R})(\text{N}=\text{NAr})\text{CO}_2\text{C}_2\text{H}_5)] \xrightarrow{\text{H}_2\text{O}}$				
				$\text{CH}_3\text{CO}_2\text{H} + \text{RCCO}_2\text{C}_2\text{H}_5$
Substituent R in $\text{CH}_3\text{COCH}(\text{R})\text{CO}_2\text{C}_2\text{H}_5$	Substituent in  N_2^+ or [Other Diazonium Ion]	Yield, %	References	Conversion Product
CH_3COCH_2	—	—	40	Pyrazole
	4- NO_2^*	—	67	Pyrazole
$\text{C}_2\text{H}_5\text{O}_2\text{CCH}_2\text{CH}_2$	—	74	113	—
	2- CH_3	88	113	—
	3- CH_3	34	113	—
	2- Cl	60	113	—
	3- Cl	72	113	—
	4- Cl	81	113	—
	2- CO_2H	90	113	—
	4- SO_3H	95	113	—
	4- NO_2	87	113	—
	(α - $\text{C}_{10}\text{H}_7\text{N}_2$)	47	113	—
	(β - $\text{C}_{10}\text{H}_7\text{N}_2$)	33	113	—
NCCH_2CH_2	—	98	112, 113	Indole
	4- NO_2	98	113	—
$\text{C}_2\text{H}_5\text{O}_2\text{CCH}_2\text{CH}_2$	—	—	68, 69	Indole
	2- Cl	—	52	—
	3- Cl	—	52	—
	4- Cl	—	52	—
	2- CH_3	—	111	Amino acid
	2- OCH_3	—	52	Indole
	3- OCH_3	—	52	Indole
	4- OCH_3	—	52	Indole
$\text{C}_6\text{H}_5\text{OCH}_2\text{CH}_2\text{CH}_2$	—	15	70	Indole
$\text{C}_2\text{H}_5\text{O}_2\text{CCH}(\text{NHCO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CH}_2$	—	Good	71	Indole

Note: References 59–118 are on pp. 177–178.

* The azo compound was isolated; upon standing or upon treatment with aqueous alkali, followed by acidification, it underwent loss of the acetyl group and cyclization to the pyrazole.

TABLE II—*Continued*

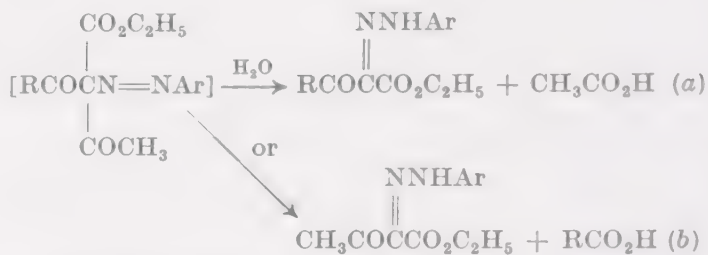
MONOSUBSTITUTED ACETOACETIC ESTERS IN THE REACTION:

$\text{CH}_3\text{COCH}(\text{R})\text{CO}_2\text{C}_2\text{H}_5 + \text{ArN}_2^+\text{X}^- \rightarrow [\text{CH}_3\text{CO}(\text{R})\text{C}(\text{N}=\text{NAr})\text{CO}_2\text{C}_2\text{H}_5] \xrightarrow{\text{H}_2\text{O}}$				
				$\text{CH}_3\text{CO}_2\text{H} + \text{RCCO}_2\text{C}_2\text{H}_5$
Substituent R in $\text{CH}_3\text{COCH}(\text{R})\text{CO}_2\text{C}_2\text{H}_5$	Substituent in  N ₂ ⁺ or [Other Diazonium Ion]	Yield, %	References	Conversion Product
	—	70	82	Indole
	—	50	82	Indole
$\text{C}_6\text{H}_5\text{COCH}_2$	—	—	41	Pyrazole
	2-CH ₃	—	40	Pyrazole
	4-CH ₃	—	40	Pyrazole
$\text{C}_6\text{H}_5\text{COCH}(\text{C}_6\text{H}_5)$	—	—	40	Pyrazole

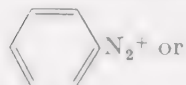
Note: References 59–118 are on pp. 177–178.

TABLE III

ACYLACETOACETIC ESTERS IN THE REACTION:

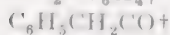
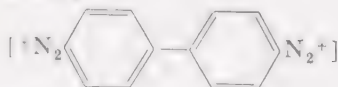
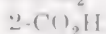
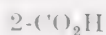
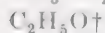


Substituent in



[Other Diazonium Ion]

Yield, %	Refer- ences	Conversion Product
—	18	—
—	18	—
—	18	—
—	83	—
—	18	—
—	18	—
—	18	—
—	18	—
—	18	—
—	18	—
—	18	—
—	18	—
—	18	—



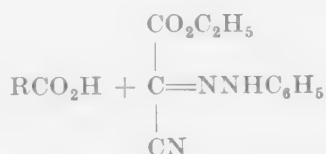
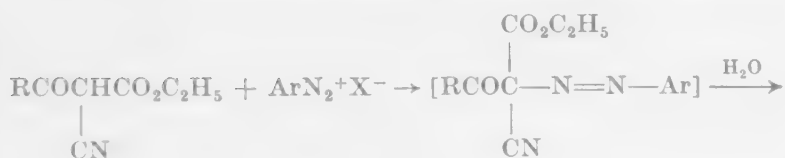
Note: References 59-118 are on pp. 177-178.

* Reaction course *b*.

† Reaction course *a*.

TABLE IV

ACYLCYANOACETIC ESTERS IN THE REACTION:




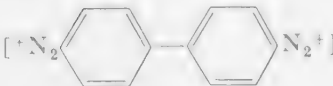
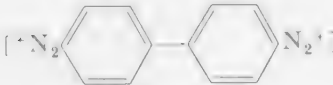

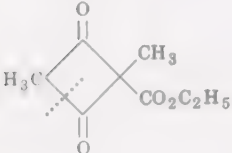
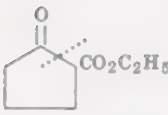
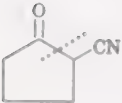
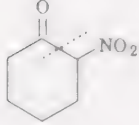
R in Ester	Substituent in	Yield, %	Refer- ences	Conversion Product
	[Other Diazonium Ion]			
CH ₃	 N ₂ ⁺ or 	—	20, 21	—
CH ₃ CH ₂	—	—	20, 21	—
(CH ₃) ₂ CH	—	—	20, 21	—
		—	20	—
(CH ₃) ₂ CHCH ₂	—	—	20, 21	—
C ₆ H ₅	—	—	20, 21	—

TABLE V
CYCLIC COMPOUNDS IN RING-OPENING REACTIONS*

Cyclic Compound†	Substituent in  N ₂ ⁺ or [Other Diazonium Ion]	Yield, %	References	Conversion Product
	4-NO ₂	Good‡	84	—
	—	96	11, 51, 53, 85, 114	Indole
	2-NO ₂	—	11	Indole
	4-NO ₂	—	11, 14	Indole
	3-CO ₂ H	70	37	Indole
	4-I	65	14	Indole
	4-OCH ₃	71	86	Indole
	3-I, 4-I, 5-I	95	14	—
	3-I, 4-OCH ₃ , 5-I	88	14	—
	[α-C ₁₀ H ₇ N ₂ ⁺]	94	53	Indole
	—	—	87	—
	—	—	88	—

Note: References 59–118 are on pp. 177–178.

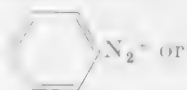
* See p. 155.

† The bond broken in the ring opening is indicated by the dotted line.

‡ The reported product is $\text{O}_2\text{NC}_6\text{H}_4\text{N}=\text{N}-\text{C}(\text{CH}_3)(\text{CO}_2\text{H})-\text{CO}-\text{CH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$.

TABLE V—*Continued*
CYCLIC COMPOUNDS IN RING-OPENING REACTIONS*

Substituent in



Cyclic Compound† [Other Diazonium Ion]	Yield, %	References	Conversion Product
	—	44	Amino acid
—	97	115, 118	Indole
—§	87	11, 54	—
2-NO ₂	—	38	Indole
4-NO ₂	—	11	—
3-OCH ₃ , 4-OCH ₃	90	49	Indole
	89	89, 116	—

Note: References 59–118 are on pp. 177–178.


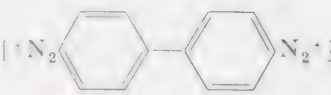
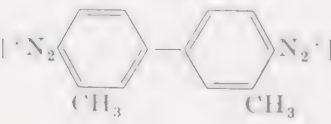
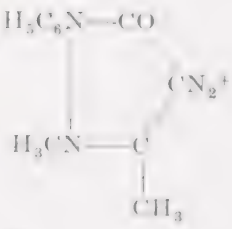

* See p. 155.

† The bond broken in the ring opening is indicated by the dotted line.

§ Methyl cyclohexanone-2-carboxylate was also coupled.

TABLE VI

1,3-DICARBONYL COMPOUNDS
(The group that is lost is italic.)


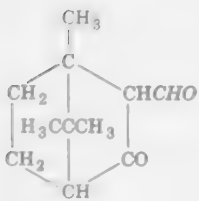
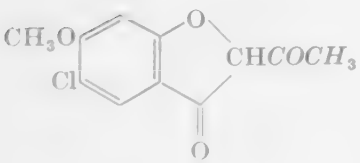
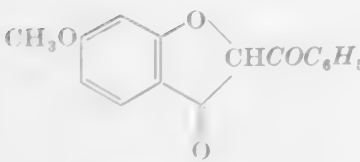
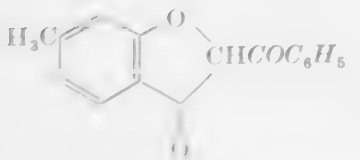
Carbonyl Compound	Substituent in  or [Other Diazonium Ion]	Yield, %	Refer- ences	Con- version Product
$\text{CH}_3\text{COCHCOCH}_3$ Cl	—	—	42	—
	—	69	90	—
$\text{CH}_3\text{COCHCOCO}_2\text{C}_2\text{H}_5$ Cl	—	—	91	—
$\text{CH}_3\text{COCHCOCH}_3$ CH ₃	—	—	43	—
	2-CH ₃	—	43	—
	4-CH ₃	—	43	—
	4-NO ₂	—	13	—
		—	43	—
		—	43	—
		—	48	—
$\text{CH}_3\text{COCHCOCH}_3$ CH ₂ CH ₃	—	—	43	—
	2-CH ₃	—	43	—
	4-CH ₃	—	43	—
	4-NO ₂	—	13	—
	4-Cl	—	13	—
	4-Br	—	13	—
		—	43	—

Note: References 59-118 are on pp. 177-178

TABLE VI—*Continued*

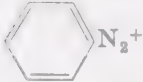
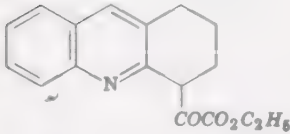
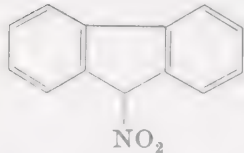
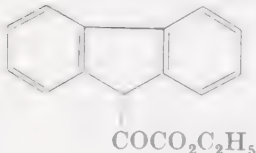
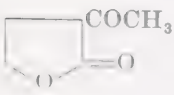
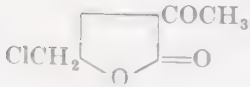
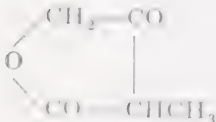
1,3-DICARBONYL COMPOUNDS

(The group that is lost is italic.)

Carbonyl Compound	Substituent in  N ₂ ⁺ or [Other Diazonium Ion]	Yield, %	Refer- ences	Con- version Product
CH ₃ COCHCOCH ₃	—	90 (as acid)	113	—
CH ₂ CH ₂ CO ₂ C ₂ H ₅	2-CH ₃	72 (as acid)	113	—
	3-CH ₃	85 (as acid)	113	—
	4-CH ₃	81 (as acid)	113	—
	4-NO ₂	85 (as acid)	113	—
C ₆ H ₅ COCHCHO	—	—	92, 93	—
 C ₆ H ₅	4-Br	—	9	—
	4-NO ₂	—	8	—
	—	—	94	—
	—	—	19	—
	—	—	19	—
	—	—	19	—

Note: References 59–118 are on pp. 177–178.

TABLE VII
MISCELLANEOUS COMPOUNDS

Starting Material	Substituent in 	Yield, %	References	Conversion Product
	—*	—	27	—
	4-OCH ₃ *	—	27	—
	4-Br*	—	27	—
	—†	—	26	—
	—‡	—	95	—
	4-NO ₂ ‡	—	25	—
	—	90-96	45, 46, 47	Amino acid
	—	83	96, 97	Amino acid
	—	—	98	—

Note: References 59-118 are on pp. 177-178.

* The reaction was run in pyridine solution.

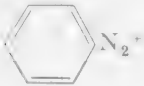
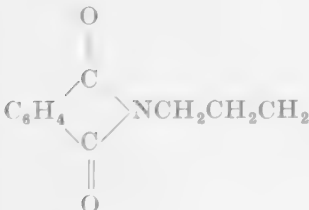
† The nitro group eliminated from the 9 position of fluorene apparently attacked the coupling product, since the *p*-nitro-phenylhydrazone of fluorenone was isolated.

‡ The ethoxalyl group was eliminated.

B. Reactions Accompanied by Decarboxylation


TABLE VIII

ACETOACETIC ACID DERIVATIVES

R in RCHCO ₂ H	Substituent in 	Yield, %	References	Conversion Product
COCH ₃				
CH ₃	—	Quant.	4, 5, 33	—
C ₂ H ₅	—	—	4, 5	—
KO ₂ CCH ₂ CH ₂	—	80	99	—
C ₆ H ₅ CH ₂	—	86	36	Indole
	3-NO ₂	80	36	—
	2-OCH ₃ , 5-OCH ₃	80	36	—
	3-OCH ₃ , 4-OCH ₃	Quant.	49	—
C ₆ H ₅ COCH ₂	—	—	40	Pyrazole
	—	86	36	Indole
	3-OCH ₃	85	36	Indole
	3-Cl	—	36	—

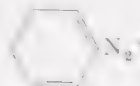
Note: References 59-118 are on pp. 177-178.

TABLE IX
CYANOACETIC ACID DERIVATIVES

R in RCHCO_2H $\text{C}\equiv\text{N}$	Substituent in 	Yield, %	References	Conversion Product
CH_3	—	—	100, 101	—
	2- CH_3	25	100, 101	—
	4- CH_3	28	100, 101	—
C_2H_5	—	31	100, 101	—
	2- CH_3	25	100, 101	—
	4- CH_3	15	100, 101, 102	—
	4- Cl	Quant.	102	—
C_6H_5	—	—	102	—
$\text{C}_6\text{H}_5\text{CH}_2$	—	30	58, 103	Amino acid
	—	Quant.	102	—
	4- CH_3	25	102	—
	4- NO_2	—	102	—

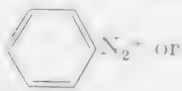
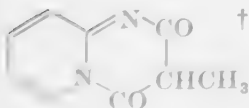
Note: References 59–118 are on pp. 177–178.

TABLE X
MALONIC ACID DERIVATIVES

R in $\text{RCH}(\text{CO}_2\text{H})_2$	Substituent in 	Yield, %	References	Conversion Product
Cl	—	—	59	—
	2- CO_2CH_3	—	59	—
CH_3	—	—	104, 105	—
	4- CH_3	—	104, 105	—
C_2H_5	—	—	104, 105	—
	2- CH_3	—	104, 105	—
$\text{HO}_2\text{CCH}_2\text{CH}_2$	—	49	113	—
$\text{C}_6\text{H}_5\text{CH}_2$	—	—	58, 103	Amino acid
	—	—	80	Azoformaldoxime

Note: References 59–118 are on pp. 177–178.

TABLE XI
MISCELLANEOUS REACTIONS

Starting Material	Substituent in  [Other Diazonium Ion]	Yield, %	References	Conversion Product
$\text{CH}_3\text{CHCO}_2\text{H}$ NO_2	—	—	28	—
CH_2 CH_2 CO CH_2 — CHCO_2H	— 2- NO_2 4- NO_2	Quant. — —	11, 56, 106 11 11	Indole — —
CH_2 CH_2 CO CH_2 — $\text{CHCONHC}_6\text{H}_5$	2- NO_2^* 4- NO_2^*	— —	11 11	— —
CH_2 CH_2 CO CH_2 — CHCO_2H	— 4- CH_3 4- NO_2 [α - $\text{C}_{10}\text{H}_7\text{N}_2^+$] [β - $\text{C}_{10}\text{H}_7\text{N}_2^+$]	Quant. Quant. — — Quant.	11, 56 56 11 56 56	Indole Indole Indole Indole Indole
CH_3 C CH_2 CO H_3CCCH_3 CH_2 CHCO_2H CH	—	—	107	—
 †	4- $\text{CO}_2\text{C}_2\text{H}_5$	89	108	—

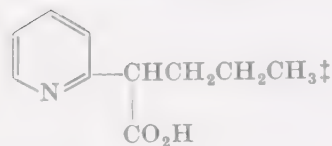
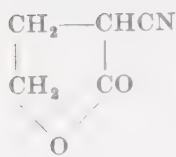
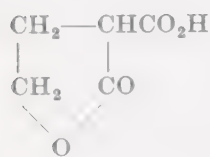
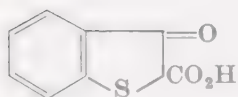
Note: References 59-118 are on pp. 177-178.

* The azo compound was isolated also.

† The product was α - $\text{C}_5\text{H}_4\text{NNHCOCH}(\text{CH}_3)=\text{NNHC}_6\text{H}_4\text{CO}_2\text{C}_2\text{H}_5$ -(p).

TABLE XI—*Continued*

MISCELLANEOUS REACTIONS

Starting Material	Substituent in	Yield, %	References	Conversion Product
	[Other Diazonium Ion]			
	4-CO ₂ H	94	15	—
	—	88	109	—
	—	83	46	Amino acid
	—	Quant.	110	—

Note: References 59–118 are on pp. 177–178.

‡ The product was 2-*n*-butyrylpyridine.

REFERENCES FOR TABLES I-XI

- ¹ Fusco and Romani, *Gazz. chim. ital.*, **76**, 419 (1946); **78**, 342 (1948).
- ² Bowack and Lapworth, *J. Chem. Soc.*, **87**, 1854 (1905).
- ³ Bulow and King, *Ann.*, **439**, 211 (1924).
- ⁴ Lapworth, *J. Chem. Soc.*, **83**, 1114 (1903).
- ⁵ Rydon and Siddappa, *J. Chem. Soc.*, **1951**, 2462.
- ⁶ Hegedus, *Helv. Chim. Acta*, **29**, 1499 (1946).
- ⁷ Feofilaktov and Zaitseva, *J. Gen. Chem. U.S.S.R.*, **13**, 358 (1943) [*C. A.*, **38**, 1211 (1944)].
- ⁸ Feofilaktov and Zaitseva, *J. Gen. Chem. U.S.S.R.*, **10**, 1391 (1940) [*C. A.*, **35**, 3606 (1941)].
- ⁹ Eastman and Detert, *J. Am. Chem. Soc.*, **70**, 962 (1948).
- ¹⁰ Tanaka, *J. Pharm. Soc. Japan*, **60**, 74 (1940) [*C. A.*, **34**, 3735 (1940)].
- ¹¹ King and L'Ecuier, *J. Chem. Soc.*, **1934**, 1901.
- ¹² Manske, *Can. J. Research*, **4**, 591 (1931).
- ¹³ Plieninger, *Ber.*, **83**, 268 (1950).
- ¹⁴ Feofilaktov and Blanko, *J. Gen. Chem. U.S.S.R.*, **11**, 859 (1941) [*C. A.*, **36**, 4096 (1942)].
- ¹⁵ Feofilaktov, *J. Gen. Chem. U.S.S.R.*, **10**, 247 (1940) [*C. A.*, **34**, 7283 (1940)].
- ¹⁶ Bulow and Schlesinger, *Ber.*, **32**, 2880 (1899).
- ¹⁷ Bulow, *Ber.*, **33**, 3266 (1900).
- ¹⁸ Stolz, *Ber.*, **33**, 262 (1900).
- ¹⁹ Bulow and Schlesinger, *Ber.*, **33**, 3362 (1900).
- ²⁰ Bulow and Baur, *Ber.*, **58**, 1926 (1925).
- ²¹ Feofilaktov and Vinogradova, *J. Gen. Chem. U.S.S.R.*, **10**, 255 (1940) [*C. A.*, **34**, 7283 (1940)].
- ²² Walker, *J. Chem. Soc.*, **127**, 1860 (1925).
- ²³ Feofilaktov, Zaitseva, and Surotkina, *J. Gen. Chem. U.S.S.R.*, **13**, 362 (1943) [*C. A.*, **38**, 1211 (1944)].
- ²⁴ Sempronj, *Gazz. chim. ital.*, **68**, 263 (1938).
- ²⁵ Rabischong, *Bull. soc. chim. France*, [3], **31**, 91 (1904).
- ²⁶ Schroeter, *Ber.*, **49**, 2697 (1916).
- ²⁷ Kalb, Schweizer, and Schimpf, *Ber.*, **59**, 1858 (1926).
- ²⁸ Barrett, Perkin, and Robinson, *J. Chem. Soc.*, **1929**, 2942.
- ²⁹ Feofilaktov, *Bull. acad. sci. U.R.S.S. Classe sci. chim.*, **1941**, 521 [*C. A.*, **37**, 2347 (1943)].
- ³⁰ Wieland, Garbsch, and Chavan, *Ann.*, **461**, 295 (1928).
- ³¹ Feofilaktov, *J. Gen. Chem. U.S.S.R.*, **21**, 362 (1951) [*C. A.*, **45**, 7551 (1951)].
- ³² Neber and Worner, *Ann.*, **526**, 173 (1936).
- ³³ Favrel and Chrz, *Bull. soc. chim. France*, [4], **41**, 1603 (1927).
- ³⁴ Wislicenus and Ruthing, *Ann.*, **379**, 229 (1911).
- ³⁵ Roy and Sen, *J. Indian Chem. Soc.*, **10**, 347 (1933).
- ³⁶ Bishop, Claisen, and Sinclair, *Ann.*, **281**, 314 (1894).
- ³⁷ Wislicenus and Densch, *Ber.*, **35**, 759 (1902).
- ³⁸ Feofilaktov and Onishchenko, *Compt. rend. acad. sci. U.R.S.S.*, **20**, 133 (1938) [*C. A.*, **33**, 1725 (1939)].
- ³⁹ Feofilaktov and Onishchenko, *J. Gen. Chem. U.S.S.R.*, **9**, 331 (1939) [*C. A.*, **34**, 379 (1940)].
- ⁴⁰ Wolff, *Ann.*, **312**, 119 (1900).
- ⁴¹ Clemo and Welch, *J. Chem. Soc.*, **1928**, 2621.
- ⁴² Favrel, *Compt. rend.*, **132**, 983 (1901).
- ⁴³ Favrel, *Bull. soc. chim. France*, [3], **27**, 193 (1902).
- ⁴⁴ Walker, *J. Chem. Soc.*, **125**, 1622 (1924).
- ⁴⁵ Feofilaktov and Vinogradova, *Compt. rend. acad. sci. U.R.S.S.*, **24**, 759 (1939) [*C. A.*, **34**, 1971 (1940)]; *J. Gen. Chem. U.S.S.R.*, **10**, 260 (1940) [*C. A.*, **34**, 7283 (1940)].
- ⁴⁶ Favrel, *Compt. rend.*, **132**, 1336 (1901).

- ¹⁰⁵ Favrel, *Bull. soc. chim. France*, [3], **27**, 324 (1902).
¹⁰⁶ Dieckmann, *Ann.*, **317**, 27 (1901).
¹⁰⁷ Betti, *Ber.*, **32**, 1995 (1899).
¹⁰⁸ Snyder and Robison, *J. Am. Chem. Soc.*, **74**, 4910 (1952).
¹⁰⁹ Feofilaktov and Onishchenko, *J. Gen. Chem. U.S.S.R.*, **9**, 325 (1939) [*C. A.*, **34**, 379 (1940)].
¹¹⁰ Friedlander, *Monatsh.*, **30**, 347 (1909).
¹¹¹ Feofilaktov and Semenova, *Akad. Nauk S.S.S.R. Inst. Org. Khim. Sintezy Org. Soedinenii, Sbornik*, **2**, 74 (1952) [*C. A.*, **48**, 592 (1954)].
¹¹² Feofilaktov and Semenova, *Akad. Nauk S.S.S.R. Inst. Org. Khim. Sintezy Org. Soedinenii, Sbornik*, **2**, 63 (1952) [*C. A.*, **48**, 666 (1954)].
¹¹³ Feofilaktov and Semenova, *Zhur. Obshchei Khim.*, **23**, 459 (1953) [*C. A.*, **48**, 4443 (1954)].
¹¹⁴ Feofilaktov, *Akad. Nauk S.S.S.R. Inst. Org. Khim. Sintezy Org. Soedinenii, Sbornik*, **2**, 103 (1952) [*C. A.*, **48**, 666 (1954)].
¹¹⁵ Polaczkowa and Porowska, *Przemysl Chem.*, **6**, 340 (1950) [*C. A.*, **46**, 3039 (1952)].
¹¹⁶ Feofilaktov, *J. Gen. Chem. U.S.S.R.*, **21**, 399 (1951) [*C. A.*, **46**, 2014 (1952)].
¹¹⁷ Feofilaktov and Ivanova, *J. Gen. Chem. U.S.S.R.*, **21**, 1851 (1951) [*C. A.*, **47**, 2698 (1953)].
¹¹⁸ Feofilaktov and Semenova, *Akad. Nauk S.S.S.R. Inst. Org. Khim. Sintezy Org. Soedinenii, Sbornik*, **2**, 98 (1952) [*C. A.*, **48**, 668 (1954)].

CHAPTER 3

THE MICHAEL REACTION*

ERNST D. BERGMANN

*Scientific Department, Ministry of Defence,
Tel-Aviv*

DAVID GINSBURG

*Chemistry Department, Israel Institute of
Technology, Haifa*

RAPHAEL PAPPO

*Department of Organic Chemistry, Hebrew University,
Jerusalem*

CONTENTS

	PAGE
INTRODUCTION	182
MECHANISMS OF THE PROCESSES INVOLVED IN THE MICHAEL REACTION . . .	184
The Normal Reaction	184
The Nature of the Anion of the Adduct	185
A Competitive Side Reaction	187
The Reverse or Retrograde Reaction	187
The "Abnormal" Michael Condensation	191
The Question of Para-Bridged Intermediates	197
Stereochemistry of the Michael Condensation	199
SCOPE AND LIMITATIONS	203
Donors	203
Reactions with Cyclopropane Derivatives	205
The System $C=C-C\equiv N$	207
Acceptors	209
α,β -Ethylenic Aldehydes (Table I)	209
Aliphatic α,β -Ethylenic Ketones (Table II)	211

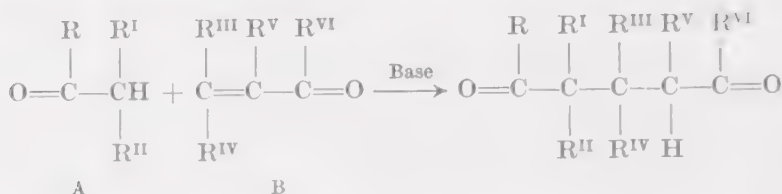
* This cooperative study was begun when the three authors were working at the Weizmann Institute of Science, Rehovoth.

	PAGE
α,β -Acetylenic Ketones	213
Aromatic α,β -Ethylenic Ketones (Tables III, IV)	216
Heterocyclic α,β -Ethylenic Ketones (Tables V, VI)	219
Cycloalkenones and Acyl Cycloalkenes (Table VII)	220
Robinson's Modification of the Michael Condensation (Table VIII)	222
<i>p</i> -Quinones and Derivatives (Table IX)	224
Acrylonitrile, Other α,β -Ethylenic Nitriles, and Their Amides (Tables X, XI, and XII)	229
α,β -Ethylenic Aliphatic Esters (Tables XIII, XIV)	234
Alcyclic and Aromatic α,β -Ethylenic Esters (Tables XV and XVI)	238
Unsaturated Keto Esters (Table XVII)	238
Aromatic α,β -Acetylenic Esters (Table XVIII)	239
Olefins with Substituents Based on Hetero Atoms (N, S, P, Tables XIX, XX, XXI)	240
2- and 4-Vinylpyridines (Table XXI)	241
Fulvenes	242
Systems That Did Not Undergo Condensation	245
SYNTHETIC APPLICATIONS	248
Synthesis of Cyclic Systems	248
Cyclopropane Rings	248
Cyclobutane Rings	248
Cyclopentane Rings	248
Cyclohexane and Condensed Alicyclic Ring Systems	249
Aromatic Ring Systems	254
Oxygen-Containing Rings	256
Piperidines and Pyridines	258
Pyrroles	261
Pyrrolizidines and Related Ring Systems	262
Synthesis of Amino Acids	263
EXPERIMENTAL CONDITIONS	264
Solvents	264
Catalysts	264
Temperature	266
EXPERIMENTAL PROCEDURES	267
γ -Acetamido- γ -carbethoxy- γ -cyanobutyraldehyde	267
5-Nitro-4,4-dimethylpentan-2-one	267
7-Keto-1-methoxy-13-methyl-3,6,7,9,10,13-hexahydrophenanthrene	267
<i>trans</i> -3-Keto-2-phenylcyclohexanecarboxylic Acid	268
Methyl 3-Keto-2-phenylcyclohexyl- α -nitroacetate	268
Triethyl α -Acetyltricarballoylate	268
Diethyl 6-Keto-4-methyl-2-heptene-1,5-dicarboxylate	269
Hexaethyl 3-Butene-1,1,2,2,3,4-hexacarboxylate	269
Diethyl α,β -Diphenylglutarate	269
Dimethyl (α -Phenyl- β -nitroethyl)malonate	269
Ethyl α -Benzoyl- γ -(2-pyridyl)butyrate	270

	PAGE
TABULAR SURVEY OF THE MICHAEL CONDENSATION	270
Table I. Michael Condensations with α,β -Ethylenic Aldehydes	270
Table II. Michael Condensations with Aliphatic α,β -Ethylenic Ketones	278
Table III. Michael Condensations with Aromatic α,β -Ethylenic Ketones	296
Table IV. Michael Condensations with Ethylenic Ketones of the Dibenzylidene- and Dicinnamylidene-Acetone Type	322
Table V. Michael Condensations with Unsaturated Ketones Containing Heterocyclic Rings	328
Table VI. Michael Condensations with 3-Acylcoumarins and Related Compounds	331
Table VII. Michael Condensations with Cycloalkenones and Acyl Cycloalkenes	336
Table VIII. Robinson's Modification of the Michael Condensation with α,β -Ethylenic Ketones	362
Table IX. Michael Condensations with Quinones and Their Derivatives	400
Table X. Michael Condensations with Acrylonitrile	415
Table XI. Michael Condensations with Unsaturated Nitriles Other than Acrylonitrile	442
Table XII. Michael Condensations with Acrylamide and Methacrylamide	447
Table XIII. Michael Condensations with Aliphatic α,β -Ethylenic Acid Derivatives	450
Table XIV. Michael Condensations with Ethyl Ethoxymethylenecyanoacetate, Diethyl Ethoxymethylenemalonate, and Diethyl Amino-methylenemalonate	478
Table XV. Michael Condensations with Aliphatic Dienic and Trienic Esters	480
Table XVI. Michael Condensations with Aliphatic α,β -Ethylenic Esters	484
Table XVII. Michael Condensations with Aromatic α,β -Ethylenic Esters	489
Table XVIII. Intramolecular Michael Condensations of Aromatic α,β -Ethylenic Esters	502
Table XIX. Michael Condensations with α,β -Ethylenic Keto Esters	504
Table XX. Michael Condensations with α,β -Acetylenic Esters	519
Table XXI. Michael Condensations with α,β -Ethylenic Nitro Compounds	523
Table XXII. Michael Condensations with α,β -Ethylenic Sulfones	535
Table XXIII. Michael Condensations with 2- and 4-Vinylpyridine, with Analogs of 2-Vinylpyridine, and with Diethyl Vinylphosphonate	537
Table XXIV. Donors Used in Michael Condensations	542

INTRODUCTION

The Michael condensation in its original scope¹⁻²¹ is the addition of an addend or donor (A) containing an α -hydrogen atom in the system $\text{O}=\text{C}-\text{CH}$ to a carbon-carbon double bond that forms part of a conjugated system of the general formulation $\text{C}=\text{C}-\text{C}=\text{O}$ in an acceptor (B)



The condensation takes place under the influence of alkaline reagents, typically alkali metal alkoxides.

The range of addends is very broad. Generally speaking, all structures $\text{O}=\text{C}-\text{CH}$ in which the hydrogen is active by the Zerewitinoff test will serve as donors in the Michael condensation. In addition, many compounds that do not meet this test of hydrogen activity, such as acetophenone, are effective Michael reactants.

Typical acceptors are α,β -unsaturated aldehydes, ketones, and acid derivatives.

By extension of the original scope, the Michael condensation has come to be understood to include addends and acceptors activated by groups other than carbonyl and carbalkoxyl. The wider scope is encompassed

¹ Michael, *J. prakt. Chem.*, [2], **35**, 349 (1887).

² Michael, *Am. Chem. J.*, **9**, 115 (1887).

³ Michael, *J. prakt. Chem.*, [2], **49**, 20 (1894).

⁴ Michael, *Ber.*, **27**, 2126 (1894).

⁵ Michael, *Ber.*, **33**, 3731 (1900).

⁶ Michael and Schulthess, *J. prakt. Chem.*, [2], **45**, 55 (1892).

⁷ von Auwers, *Ber.*, **24**, 307 (1891).

⁸ von Auwers, Koebner, and v. Meyenburg, *Ber.*, **24**, 2887 (1891).

⁹ von Auwers, *Ber.*, **26**, 364 (1893).

¹⁰ von Auwers and Jacob, *Ber.*, **27**, 1115 (1894).

¹¹ von Auwers, *Ber.*, **28**, 1130 (1895).

¹² Knoevenagel, *Ann.*, **281**, 25 (1894), especially p. 33.

¹³ Knoevenagel, *Ann.*, **281**, 25 (1894), especially p. 53.

¹⁴ Knoevenagel, *Ann.*, **289**, 131 (1896), especially p. 170.

¹⁵ Knoevenagel, *Ann.*, **297**, 185 (1897).

¹⁶ Merling, *Ber.*, **38**, 979 (1905).

¹⁷ Knoevenagel and Schwartz, *Ber.*, **39**, 3441 (1906).

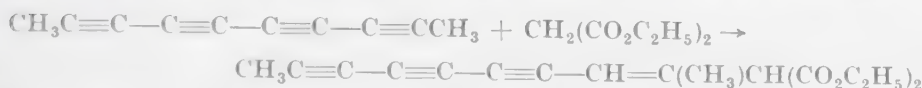
¹⁸ Knoevenagel and Mottek, *Ber.*, **37**, 4464 (1904).

¹⁹ Knoevenagel and Speyer, *Ber.*, **35**, 395 (1902).

²⁰ Connor and McClellan, *J. Org. Chem.*, **3**, 570 (1938).

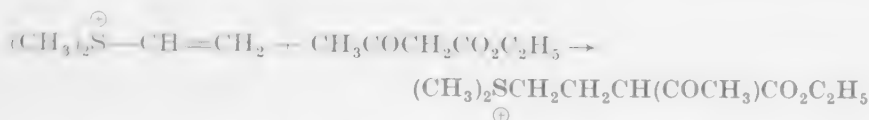
²¹ H. Hantzsch, *Chemische Reagenzien und Reagenzien-Verbindungen*, Berlin-Grosshans-Verlag, 1930.

by this survey, which therefore includes as donors nitriles, nitro compounds, sulfones, and certain hydrocarbons such as cyclopentadiene, indene, and fluorene that contain sufficiently reactive hydrogen atoms. It also includes as acceptor molecules a vinylsulfonium compound²² and certain hydrocarbons of permanent polar character (finite dipole moment) such as fulvenes. Another hydrocarbon acceptor is the conjugated tetraacetylenic compound which adds diethyl sodiomalonate as shown.^{22a}



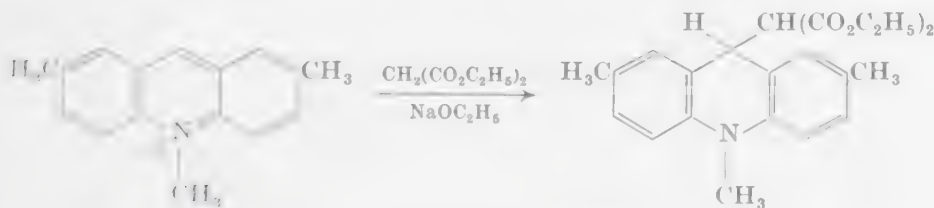
The relatively few Michael condensations in which acetylenic aldehydes, ketones, and esters serve as acceptors are also considered.

The interesting examples of activation of an ethylenic double bond by a neighboring sulfonium group provided by the observation²² that vinyltrimethylsulfonium bromide adds methyl acetoacetate and diethyl malonate in the presence of aqueous sodium hydroxide, according to the following equation,



are good illustrations of the mechanism of the Michael reaction, as set out in the following section.

Unsaturated cyclic quaternary ammonium salts can also act as acceptors in the presence of bases. A recent example is furnished by the 2,7,10-trimethylacridinium halides which react with diethyl malonate in the presence of sodium ethoxide as shown in the accompanying equation.^{22b}



²² Doering and Schreiber, *J. Am. Chem. Soc.*, **77**, 514 (1955).

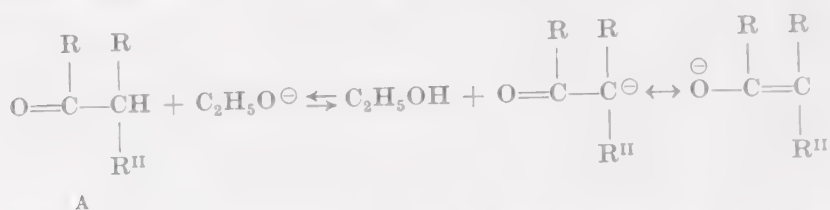
^{22a} Bohlmann, Inhoffen, and Politt, *Ann.*, **604**, 207 (1957).

^{22b} Dimroth and Criegee, *Chem. Ber.*, **90**, 2207 (1957). Other examples are given by Kroehnke and Honig, *Chem. Ber.*, **90**, 2215 (1957); Kroehnke and Vogt, *Ann.*, **600**, 211 (1956), and *Chem. Ber.*, **90**, 2227 (1957). These reactions recall older observations of the reactions of unsaturated cyclic quaternary ammonium pseudo bases with ethyl acetoacetate and with nitroparaffins: Kaufmann, *Chem. Zentr.*, **1912**, **II**, 978; Leonard and Leubner, *J. Am. Chem. Soc.*, **71**, 3405 (1949); Leonard, Leubner, and Burk, *J. Org. Chem.*, **15**, 979 (1950).

MECHANISMS OF THE PROCESSES INVOLVED IN THE MICHAEL REACTION

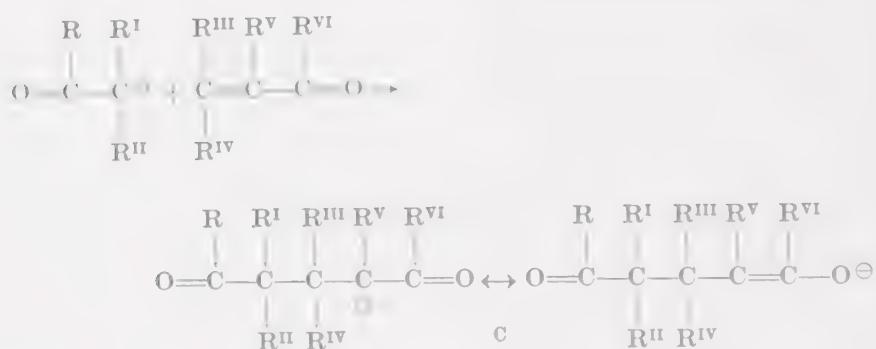
The Normal Reaction

From the nature of the alkaline reagents that cause the Michael condensation to occur, it is logical to suppose that they act by removing the α -hydrogen atom from the donor as a proton. The residual anion is



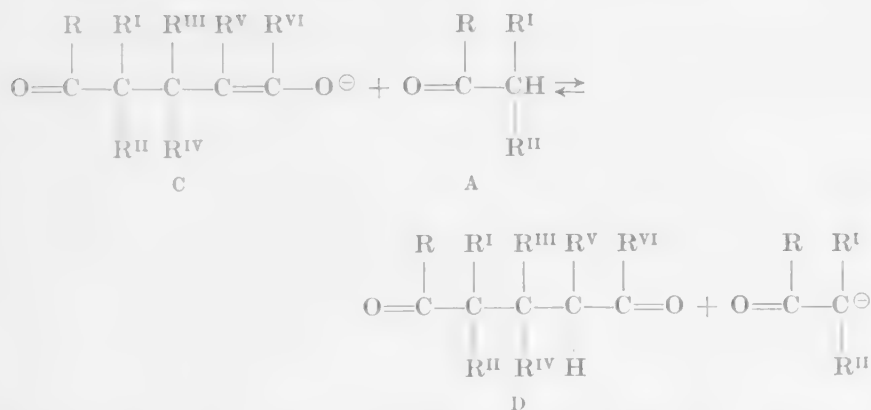
presumably to be viewed as a hybrid of the enolate ion form and the carbanion form, as depicted here, though the subsequent condensation is most readily visualized as involving the carbanion.

The condensation proper occurs when a new bond is formed between the electron-rich carbon of this ion and the most electron-poor carbon of the conjugated system in the acceptor, namely, the β -carbon atom. Where the acceptor has (as shown) carbonyl activation of the α,β double bond, the carbanion product C is a resonance hybrid. It is noteworthy that ability of acceptors to serve in the Michael condensation is enhanced by polarizing substituents (R^{III} , R^{IV} , R^{V}) that stabilize the ions C.



The proton that converts the ionized product (C) into the keto form isolated (D) may come from another donor molecule. This interpretation accounts for the fact that much less than the equivalent amount of basic reagent often suffices to bring about the condensation. Where a full equivalent of base is employed, the proton is supplied by neutralization of the reaction system.

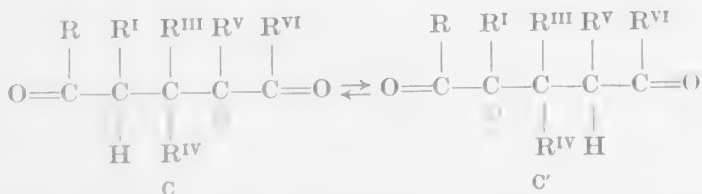
The over-all reaction has, then, the effect of 1,4 addition of the donor (in fragments $\text{O}-\text{C}-\text{C}-$ and $-\text{H}$) to the conjugated system of the acceptor.



The foregoing description obviously does not apply to those condensations, included as Michael reactions in the larger sense, in which the acceptor is an unsaturated hydrocarbon of permanent polar character. Here the product C must be formulated exclusively as a carbanion, and the over-all reaction has the appearance of 1,2 addition of the donor RH (as R— and —H) to the polarized double bond.

The Nature of the Anion of the Adduct

Where R^{II} is hydrogen, the carbanion C may undergo a proton shift. It must be supposed that the anion readily assumes the form C' if this

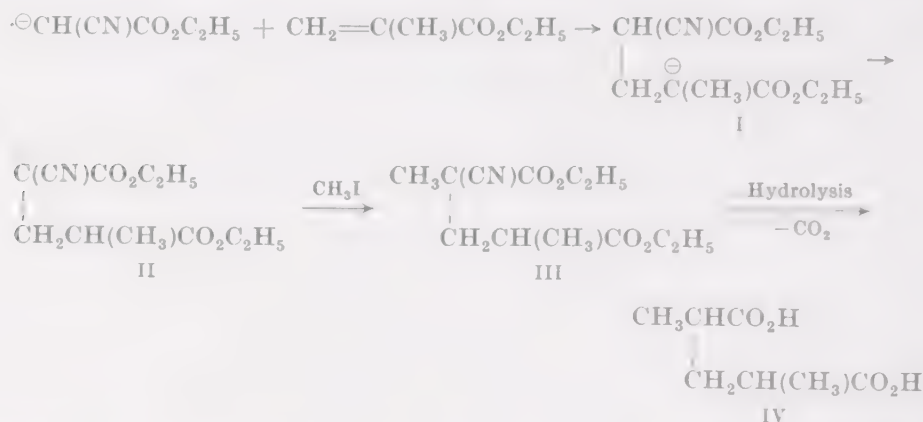


is more stable than C, as may be the case if the substituent R^{I} makes the proton of the group $\text{R}^{\text{I}}\text{CH}$ more highly acidic than that of $\text{R}^{\text{V}}\text{CH}$.

Although on direct isolation the same product is obtained from C and from C', the reactions carried out on the anion may disclose when the change has taken place, as in the following example.²³ The Michael product from ethyl cyanoacetate and ethyl methacrylate (with a full equivalent of base) can be methylated in alcoholic solution with methyl iodide. Upon hydrolysis and decarboxylation, *z,z'*-dimethylglutaric

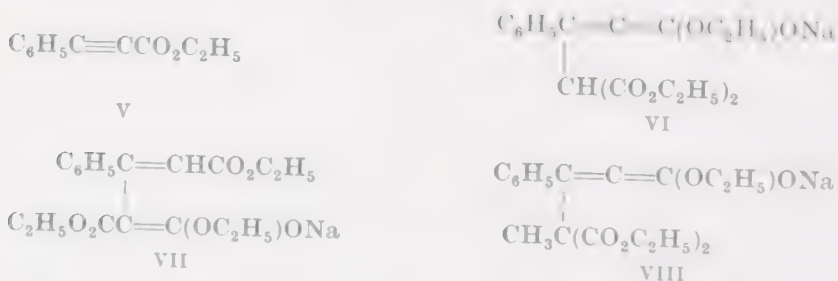
²³ Thorpe and Young, *J. Chem. Soc.*, **77**, 940 (1900).

acid (IV) is obtained. This must be derived from III, and the anion is then better represented as II than I, which would be the primary result of the addition outlined in the foregoing.



Many similar observations of this rearrangement, which is not in itself part of the Michael reaction, have been made in the course of efforts to establish Michael mechanisms.²⁴

From one particular example, it appears that the rearrangement may be impeded in non-hydroxylic solvents.^{25,26} Ethyl phenylpropiolate (V) with diethyl sodiomalonate in *inert solvents* gives a yellow sodium salt and in *ethanol solution* a colorless isomer. The formulas VI (before rearrangement) and VII (after rearrangement), respectively, have been assigned to these salts. Diethyl sodiomethylmalonate in benzene also gives a yellow compound VIII with ethyl phenylpropiolate, but no colorless isomer; this is attributed to the lack of an α -hydrogen atom in VIII that would permit shift to the form analogous to VII. It should



be noted that the structures indicated for VI and VIII do not fully explain their yellow color.

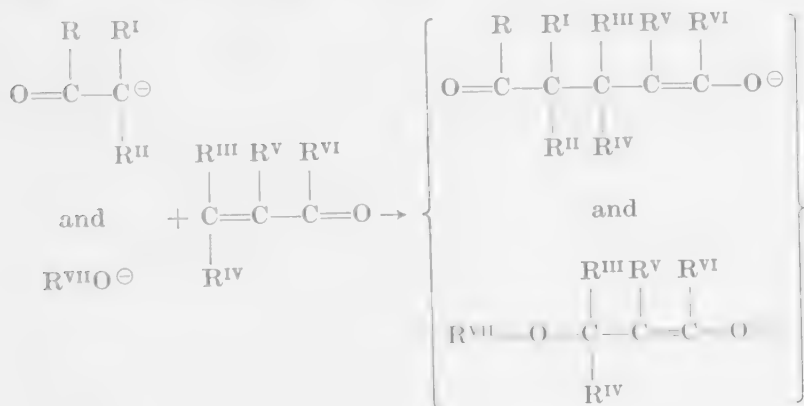
²⁴ Ingold and Powell, *J. Chem. Soc.*, **119**, 1976 (1921).

²⁵ Gidvani and Kon, *J. Chem. Soc.*, **1932**, 2443.

²⁶ Gidvani, Kon, and Wright, *J. Chem. Soc.*, **1932**, 1027.

A Competitive Side Reaction

Compounds of the type formulated above as acceptors tend to undergo addition reactions with anions in general, e.g., with alkoxide anions, which are frequently used as catalysts in the Michael reaction. In such cases, the catalyst competes with the donor for the acceptor molecule.



Although this possibility should always be borne in mind, it seems that only acceptors in which $\text{R}^{\text{III}} = \text{R}^{\text{IV}} = \text{H}$ (acrylates, acrylonitrile) add alkoxide anions avidly enough to interfere with the Michael reaction. It is preferable with these acceptors to carry out the condensation without solvent or in non-hydroxylic media.²⁷

The Reverse or Retrograde Reaction

The Michael reaction is a reversible process: adducts D can be split into precursors A and B by the same catalysts that effect the condensation.²⁸ A tendency toward such retrogression can be combatted to a degree by using an excess of one of the reactants; this appears to be a case of mass action affecting an equilibrium. Although few quantitative data are available on the position of the equilibrium, it appears that low temperature favors condensation and elevated temperature retrogression.²⁹ Furthermore, retrogression is more likely to occur when the condensation is slow; one of the factors causing slow condensation is the presence of a large number of substituents (R^{III} , R^{IV} , R^{V}) at the α,β double bond of the acceptor molecule (see p. 247). These two effects are exemplified in

²⁷ Koelsch, *J. Am. Chem. Soc.*, **65**, 437 (1943).

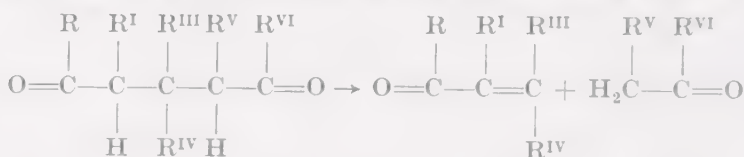
²⁸ Grob and Baumann, *Helv. Chim. Acta*, **38**, 594 (1955).

²⁹ Dornow and Boberg, *Ann.*, **578**, 101 (1952).

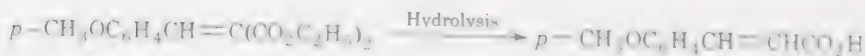
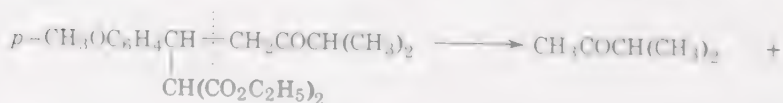
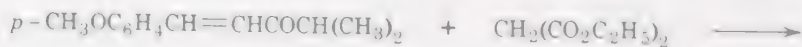
the following table in which the yields of condensation product obtained possibly represent the equilibria attained.

Reaction between Diethyl Malonate and	Yield of Adduct at	
	100°	25°
Ethyl crotonate	65	?
Ethyl cinnamate	35	?
Ethyl β,β -dimethylacrylate	30	70
Ethyl α,β,β -trimethylacrylate	Trace?	?

Whenever at least one of the substituents R^I and R^{II} in the donor is hydrogen, the general formulation of the condensation product acquires



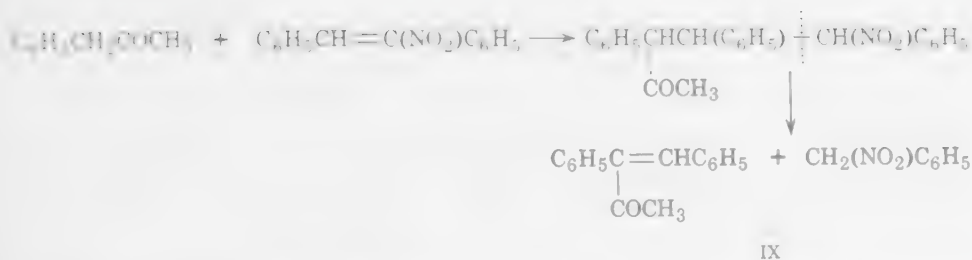
the symmetry of a 1,5-diketopentane with hydrogen atoms in the 2 and 4 positions. With such a structure, retrogression can occur to give fragments different from the starting materials. In this process, the bond broken is the one that was originally α,β in the acceptor; the remainder of this end of the molecule is then isolated as a fragment having $O-C-CH$ ("donor") structure. At the same time, the original donor reappears with $C-C-C=O$ ("acceptor") structure. The combination of condensation and retrogression in such cases has the net effect of transferring an alkylidene substituent from the α -carbon of the original acceptor to the α -carbon of the original donor. Thus, the Michael condensation between phenylacetone and α -nitrostilbene gives, *inter alia*, 3,4-diphenyl-3-buten-2-one (IX),²⁹ and the condensation of isopropyl



p-methoxybenzylidenemethyl ketone with diethyl malonate, when carried out in ethanol as solvent, gives *p*-methoxycinnamic acid.³⁰ (See equations at top of p. 189.)

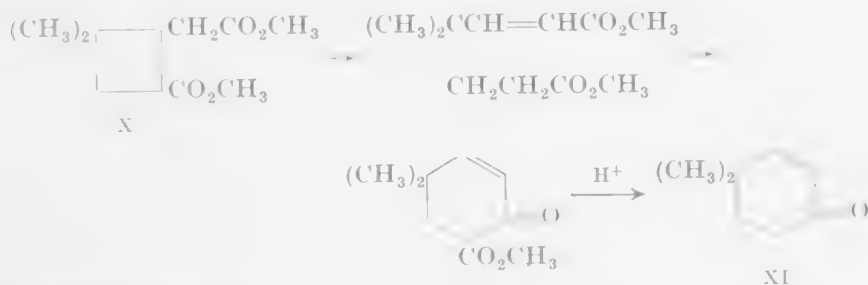
Cleavage formally identical with this can occur in molecules of suitable structure, even though they were not formed by a Michael reaction. The

³⁰ Vorlaender and Knoetzsche, *Ann.*, **294**, 317 (1897), especially p. 334.

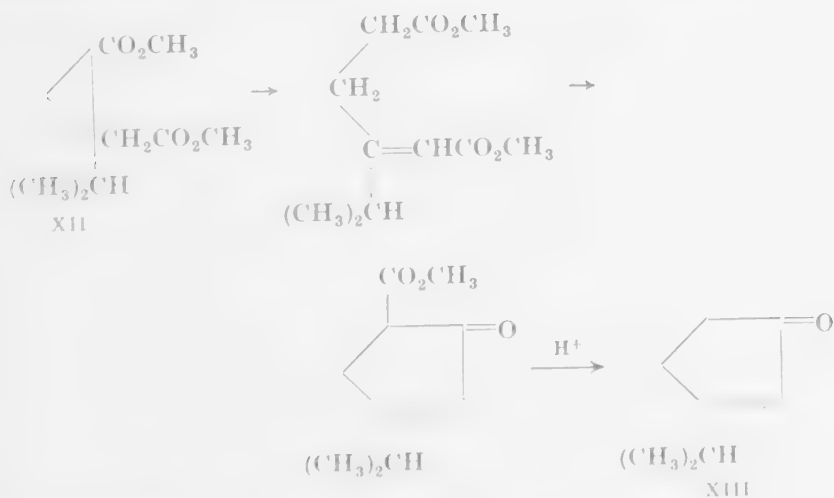


Following examples from the chemistry of natural products illustrate cleavages that may be designated retrograde Michael reactions in a formal sense.

1. Dimethyl oaryophyllenate (X) is converted by successive treatments with sodium amide in xylene at 130° and with dilute hydrochloric acid into 4,4-dimethyl-2-cyclohexenone (XI).³¹



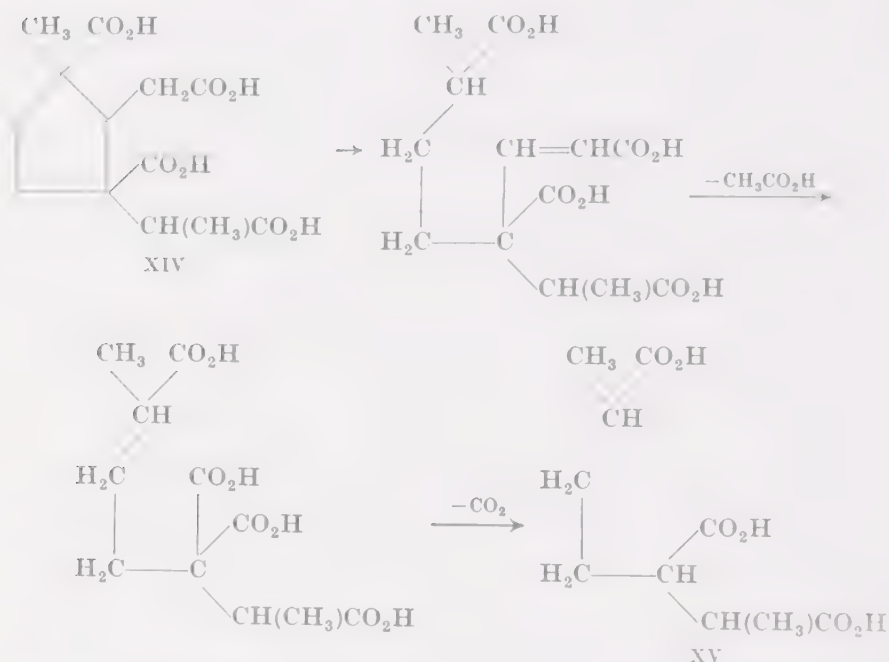
2. Dimethyl γ -tanacetonedicarboxylate (XII) is analogously converted into tanacetophorone (XIII).³²



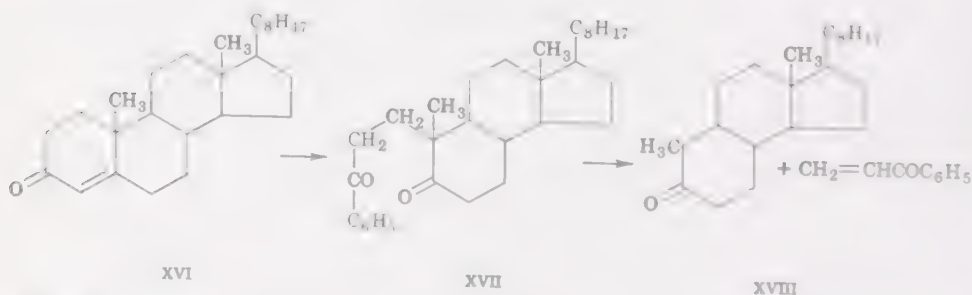
³¹ Eschenmoser and Fuerst, *Experientia*, **7**, 290 (1951).

³² Wallach, *Ann.*, **388**, 49 (1912).

3. The conversion of santonic acid (XIV) into santoronic acid (heptane-2,3,6-tricarboxylic acid, XV) has been formulated as follows:³²



4. The phenyl ketone XVII, obtained from 4-cholesten-3-one (XVI), is converted (in its intramolecular aldol form) by heating with alkali at 200–240° to XVIII and vinyl phenyl ketone, which decomposes further into formaldehyde and acetophenone.³⁴



5. Pyrolysis of the keto aldehyde XIX gives XX and 2-dodecenal.^{35,36}
6. Similarly, XXI is converted to 2-methylcyclohexanone and XXII.³⁷

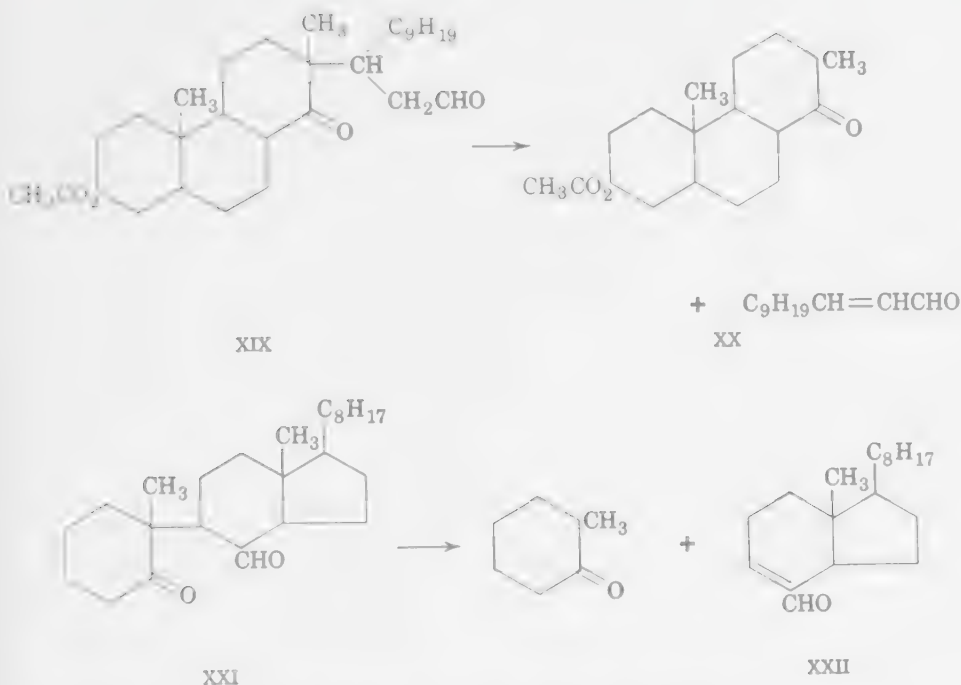
³² Woodward, Brutschy, and Baer, *J. Am. Chem. Soc.*, **70**, 4216 (1948).

³⁴ Julia, Eschenmoser, Heusser, and Tarköy, *Helv. Chim. Acta*, **36**, 1885 (1953).

³⁵ Achtermann, *Hoppe-Seyler's Z. physiol. Chem.*, **225**, 141 (1934).

Laucht, *Hoppe-Seyler's Z. physiol. Chem.*, **237**, 236 (1935).

Cornforth, Hunter, and Popják, *Biochem. J.*, **54**, 590 (1953).



Other retrogressions of this type may take place by heating or under base catalysis.³⁸⁻⁴⁷

The "Abnormal" Michael Condensation

When the Michael condensation product from ethyl β,β -dimethylacrylate and ethyl α -cyanopropionate is methylated (with sodium ethoxide and methyl iodide), the product upon hydrolysis and partial decarboxylation is $\alpha,\alpha',\beta,\beta'$ -tetramethylglutaric acid (XXVI).²³ This carbon skeleton shows that the methylation product before hydrolysis is XXV. *In vivo*, XXV probably can only arise by methylation of XXIV, where the hydrogen atom replaced is doubly activated (enolizable), because it is generally assumed that (singly activated) α -hydrogen atoms like those in XXIII (the alternative possible precursor of XXV) cannot be methylated

³⁸ Hill, *J. Chem. Soc.*, **1928**, 256.

³⁹ Leonard, Simon, and Felley, *J. Am. Chem. Soc.*, **73**, 857 (1951).

⁴⁰ Vorlaender, *Ber.*, **33**, 3185 (1900).

⁴¹ Vorlaender and Koethner, *Ann.*, **345**, 158 (1906).

⁴² Meerwein, *Ber.*, **53**, 1829 (1920).

⁴³ Smith and Engelhardt, *J. Amer. Chem. Soc.*, **71**, 2676 (1949).

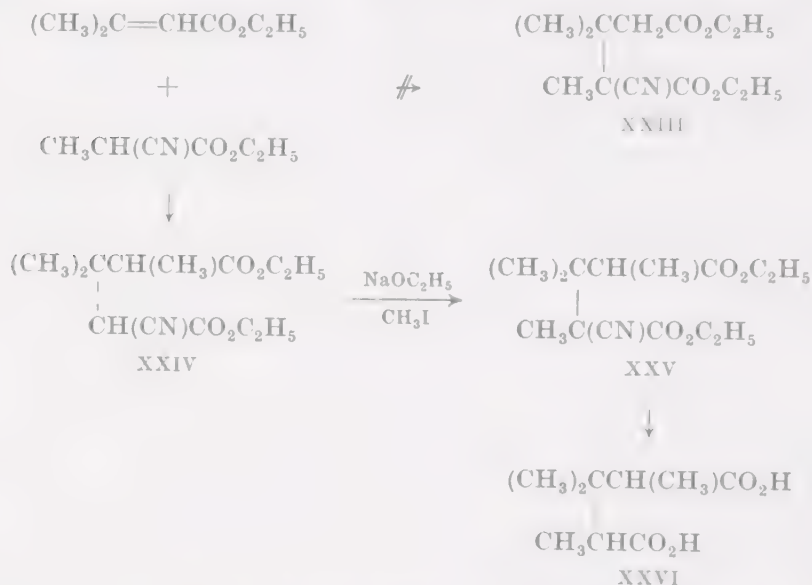
⁴⁴ Cornelson and Kostanecki, *Ber.*, **29**, 240 (1896).

⁴⁵ Kostanecki and Rossbach, *Ber.*, **29**, 1488 (1896).

⁴⁶ Meerwein, *J. prakt. Chem.*, [2], **97**, 225 (1918).

⁴⁷ Arigoni, Viterbo, Duennenberger, Jeger, and Ruzicka, *Helv. Chim. Acta*, **37**, 2306 (1954).

by sodium ethoxide plus methyl iodide.* (Hydrolysis of the primary adduct gives α,β,β -trimethylglutaric acid,⁴⁹ which does not permit differentiation between XXIII and XXIV.) The initial condensation product must therefore be not the expected ("normal") XXIII but the ester XXIV, which is formally the result of adding the donor molecule as the fragments CH_3- and $-\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$. This is called the "abnormal" Michael reaction; in this and similar cases studied by



Thorpe and co-workers, the products formed were attributed to literal addition of a methyl group as one portion of the donor. "Abnormal" addition of diethyl methylmalonate involves the apparent adding of the fragments $\text{C}_2\text{H}_5\text{OCO}-$ and $-\text{CH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$.

In some systems, it is observed that the course of the reaction can be varied at will by the amount of condensing agent employed. For example,⁵⁰ diethyl malonate and ethyl crotonate give the normal adduct, triethyl 2-methylpropane-1,1,3-tricarboxylate (XXVII), which, having an enolizable hydrogen atom, can be methylated to triethyl 3-methylbutane-2,2,4-tricarboxylate (XXVIII). The adduct XXVIII is also obtained from ethyl crotonate and diethyl *methylmalonate* in the presence of one-sixth equivalent of sodium ethoxide. If a *full* equivalent of the condensing agent is employed, however, an isomer of XXVIII is formed; this must have the "abnormal" structure XXIX, for it contains an

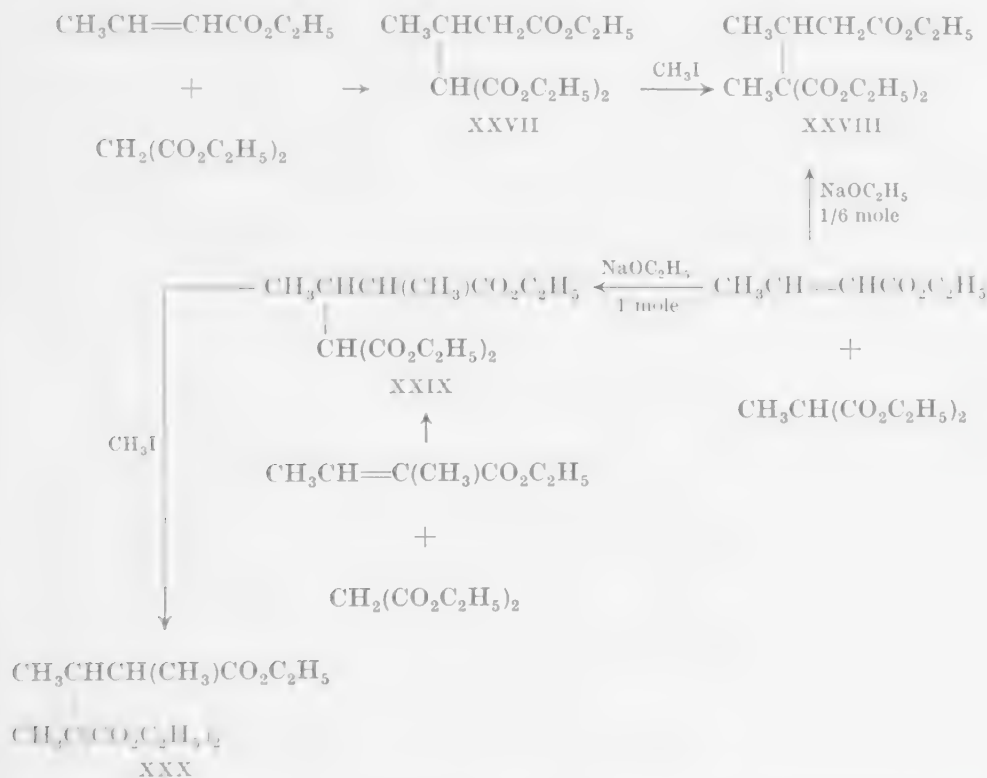
* There are occasional observations to the contrary.⁴⁸

⁴⁸ Schlenk, Hillemann, and Rodloff, *Ann.*, **487**, 135 (1931).

⁴⁹ Cf. Michael and Ross, *J. Am. Chem. Soc.*, **53**, 1150 (1931).

⁵⁰ Michael and Ross, *J. Am. Chem. Soc.*, **52**, 4598 (1930).

enolizable hydrogen atom and can be methylated by sodium ethoxide and methyl iodide to yield XXX. Furthermore, the isomer XXIX can be obtained by the Michael condensation of ethyl tiglate and diethyl malonate, though this synthesis provides valid evidence only if the condensation takes the "normal" course. In contrast to the behavior of

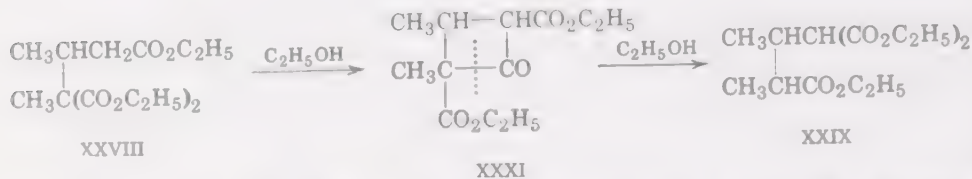


XXIX, when XXVIII is treated again with sodium ethoxide and subsequently methyl iodide, retrogression takes place to ethyl crotonate and diethyl methylmalonate, the latter being further methylated to diethyl dimethylmalonate.

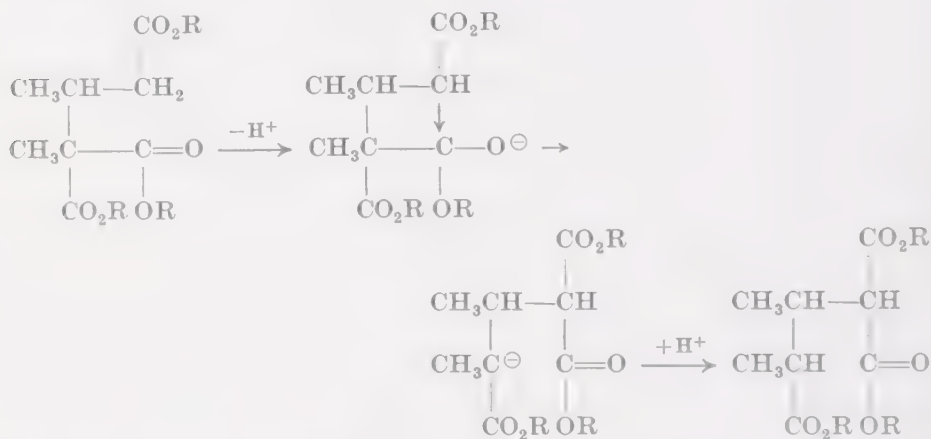
The most widely accepted explanation for the "abnormal" reaction is that of Holden and Lapworth.⁵¹ The primary product of the Michael condensation always has the normal formula (e.g., XXVIII from ethyl crotonate and diethyl methylmalonate), however, it is stable only when small quantities of catalyst are employed. In the presence of larger quantities of catalyst, a Dieckmann condensation is assumed to occur (XXVIII→XXXI). This cyclization may be facilitated by the presence of a relatively large number of substituents, which could cause a change

⁵¹ Holden and Lapworth, *J. Chem. Soc.*, **1931**, 2368.

in the valence angles, as proposed by Ingold in other cases.^{52,53} The cyclobutanone derivative XXXI in turn is also unstable, particularly as a consequence of the β -keto ester structure; accordingly, it is alcoholized to XXIX, which is the product actually obtained.



A variation of the Holden-Lapworth mechanism proposed later⁵⁴ is based on the assumption that the intermediary product is not a cyclobutanone derivative but the anion of a hemiacetal. This yields, for the reaction of ethyl crotonate with diethyl methylmalonate, the following reaction sequence.



It was emphasized that the C—C linkage connecting the hemiacetal carbon with the CHCO_2R group is "highly polarized" (symbolized \downarrow), but the significance of this statement is not clear. An analogous mechanism was suggested for the abnormal Michael reaction between diethyl methylmalonate and ethyl tetrolate.

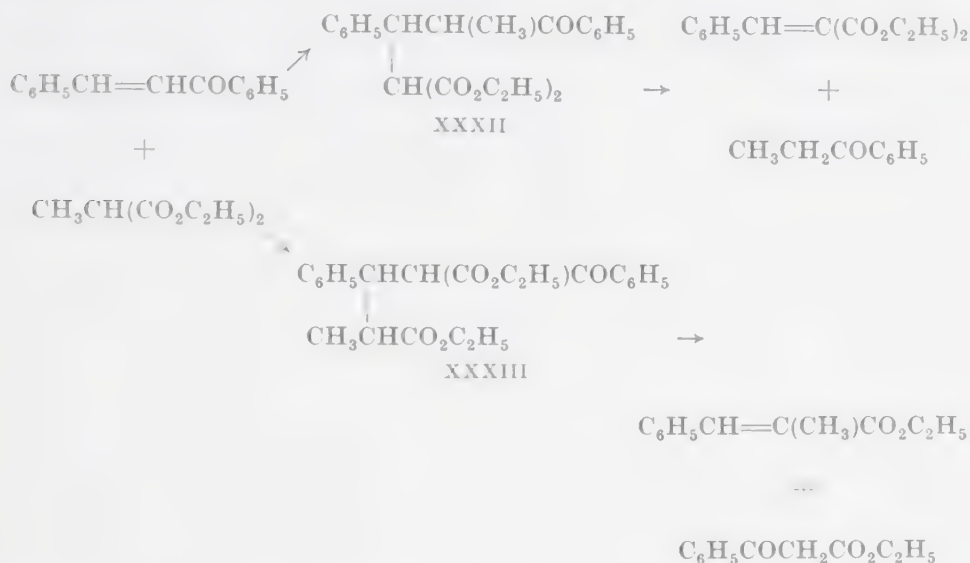
A possible means of distinguishing between the mechanisms of Thorpe and of Holden and Lapworth should be to use an acyl group in the acceptor in place of the carbalkoxy group, i.e., to use an unsaturated ketone rather than an ester. However, an attempt to make the distinction in this way was confounded by instability of the condensation

⁵² Ingold, *J. Chem. Soc.*, **119**, 305 (1921).

⁵³ Ingold, *J. Chem. Soc.*, **119**, 951 (1921).

⁵⁴ Henecka, *Fortschr. chem. Forsch.*, **1**, 685 (1950).

product. Benzylideneacetophenone and diethyl methylmalonate should give XXXII according to Thorpe, and XXXIII according to Holden and Lapworth. In fact, neither of the two compounds was obtained, but instead a mixture of retrogression products, ethyl α -methylcinnamate and ethyl benzoylacetate. These appear to be compatible only with



formula XXXIII, as indicated in the reaction scheme, because if XXXII were formed it would decompose into diethyl benzylidenemalonate and propiophenone.*

Additional evidence on mechanism was sought, with only limited success, by investigations of the condensation of diethyl benzylmalonate with diethyl fumarate,^{56,57} of diethyl benzylmalonate with *trans*-dibenzoyl-ethylene and α -chlorodibenzoyl-ethylene,⁵⁸ of diethyl methylmalonate with ethyl cyclohexene-1-carboxylate and ethyl α -ethylcrotonate,⁵⁹ and of diethyl ethylmalonate with ethyl tiglate.⁶⁰ Though no direct proof was obtained, this work tended to support the Holden-Lapworth view.^{59,61}

* An effort by Michael and Ross⁵⁵ to invalidate this conclusion, on the basis that the observed retrogression products could be derived from an adduct of two molecules of benzylideneacetophenone and one molecule of diethyl methylmalonate (see p. 308), failed on account of inability to prepare such a product from diethyl methylmalonate, in spite of its ready preparation from diethyl malonate.

⁵⁵ Michael and Ross, *J. Am. Chem. Soc.*, **55**, 1632 (1933).

⁵⁶ Duff and Ingold, *J. Chem. Soc.*, **1934**, 87.

⁵⁷ Rydon, *J. Chem. Soc.*, **1935**, 420.

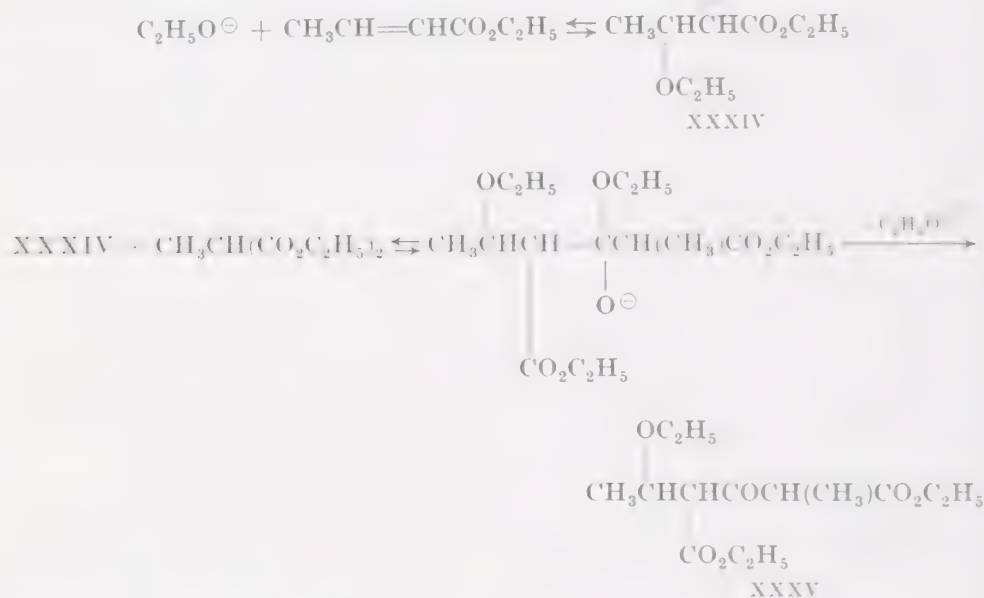
⁵⁸ Gardner and Rydon, *J. Chem. Soc.*, **1938**, 45.

⁵⁹ Gardner and Rydon, *J. Chem. Soc.*, **1938**, 48.

⁶⁰ Gardner and Rydon, *J. Chem. Soc.*, **1938**, 42.

⁶¹ Cf. Ingold and Rydon, *J. Chem. Soc.*, **1935**, 857.

Attention has recently been called⁶² to the fact that higher yields of "abnormal" Michael products are often obtained from the usual starting materials than by subjecting the "normal" product (synthesized independently) to Michael reaction conditions. This appears to mean that the "normal" product is not necessarily an intermediate in the "abnormal" reaction. Consideration of the experimental results obtained in the condensation of ethyl crotonate and diethyl methylmalonate led to the following suggested pathway of reaction.⁶³ The full equivalent of base required for the abnormal reaction permits the assumption of initial bond formation between the reactants by a kind of Claisen condensation involving an anion (XXXIV) formed from the base and the acceptor.



Base-catalyzed loss of ethanol from intermediate XXXV would give the ester XXXVI. This ester may undergo an intramolecular Michael reaction with formation of the cyclobutanone intermediate XXXI postulated by Holden and Lapworth. Alternatively, it was suggested⁶⁴ that the cyclic intermediate may not have significant independent existence, but that the ester XXXVI can change directly to the observed abnormal product XXXVII by concerted alcoholysis and addition (see equations on p. 197).

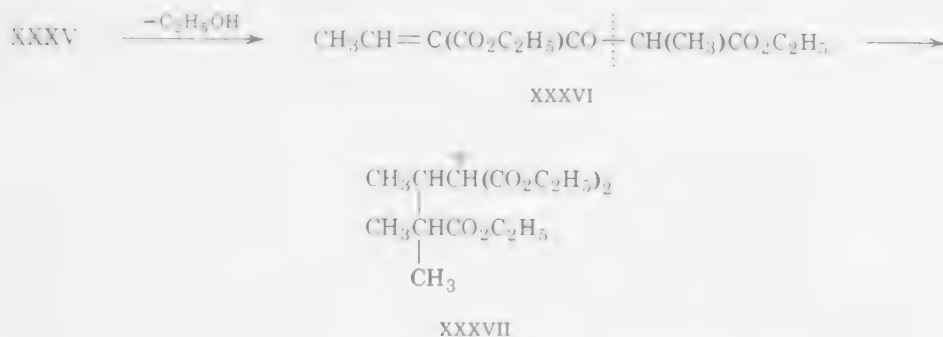
A recent kinetic study⁶⁴ of the abnormal reaction between diethyl fumarate and diethyl ethylmalonate showed that the donor anion and diethyl fumarate combine rapidly to form the anion of the normal product

⁶² P. R. Shafer, Ph. D. Thesis, University of Wisconsin, 1951.

⁶³ Shafer, Loeb, and Johnson, *J. Am. Chem. Soc.*, **75**, 5963 (1953).

⁶⁴ Tsuruta, Yasuhara, and Furukawa, *J. Org. Chem.*, **18**, 1246 (1953).

(distinguished from the abnormal product by specific gravity measurements). Isomerization of this anion to that of the abnormal product was observed to follow as a slow step. It was also observed that excess free diethyl ethylmalonate suppressed the abnormal reaction even when sodium ethoxide equivalent to the diethyl fumarate was present. This led to the deduction that the first-formed anion can be stabilized by the abstraction of hydrogen ion from free diethyl ethylmalonate in a fast reaction competitive with the isomerization.



Definitive evidence that the "abnormal" reaction involves migration of a carboxyl group (in some form or other) has at last been obtained by isotopic tracer experiments. When ethyl crotonate containing C^{14} in the carboethoxyl group was condensed with diethyl methylmalonate, the product was found to result from migration of the labeled carbon atom.⁶⁵ Enrichment of carboethoxyl groups with O^{18} in ethyl crotonate, ethyl cinnamate, and diethyl methylmalonate provided further evidence that the condensation of either of the first two with the last (using one equivalent of base as catalyst to favor "abnormal" reaction) proceeds by carboethoxyl migration.⁶⁶⁻⁶⁸

With this evidence in hand, it can be firmly concluded that the Holden-Lapworth mechanism is basically correct, though the modifications suggested by Johnson⁶⁴ provide the most plausible view of the detailed reaction course.

The Question of Para-Bridged Intermediates

The condensation of 3-methyl-2-cyclohexenone (XXXVIII) and diethyl malonate presents features that have been rationalized^{69,70} in a fashion

⁶⁵ Shimamura, Inamoto, and Suehiro, *Bull. Chem. Soc. Japan*, **27**, 221 (1954) [*C.A.*, **49**, 7494 (1955)].

⁶⁶ Swan, *J. Chem. Soc.*, **1955**, 1039.

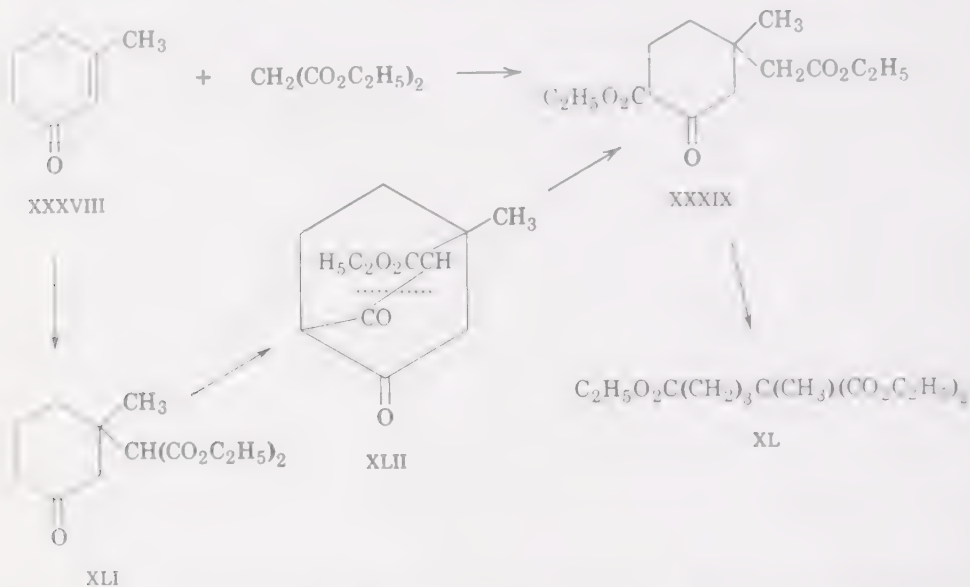
⁶⁷ Samuel and Ginsburg, *J. Chem. Soc.*, **1955**, 1288.

⁶⁸ Cf. Baker and Rothstein, *Chemistry & Industry*, **1955**, 776.

⁶⁹ Farmer and Ross, *J. Chem. Soc.*, **127**, 2358 (1925).

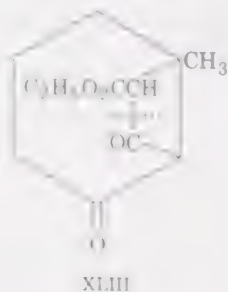
⁷⁰ Farmer and Ross, *J. Chem. Soc.*, **1926**, 3233.

consistent with and tending to support the Holden-Lapworth cyclobutanone intermediate. Carried out at room temperature and with one equivalent of sodium ethoxide, the reaction leads to only one identified product, the diethyl ester XXXIX. At the temperature of boiling ethanol, this compound is accompanied by a product of ethanolysis, the open-chain triethyl ester XL.

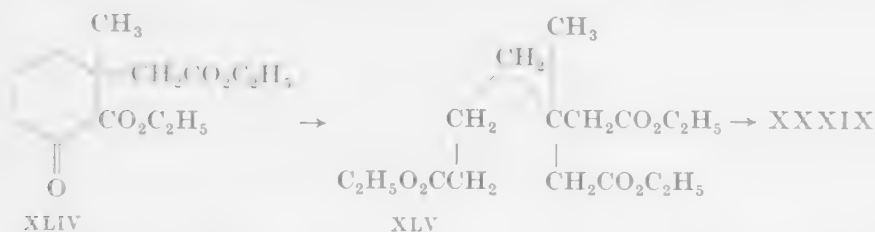


In this condensation, the "abnormal" position in which the carboethoxy portion of the donor molecule appears is para rather than ortho on the allycyclic ring. By way of explanation, it has been postulated that the primary product would be XLI, from the normal condensation; this was believed to be converted by a Dieckmann reaction into the bicyclic diketone XII. Ethanolysis of the diketone in the manner indicated by the broken line was believed to lead to XXXIX.

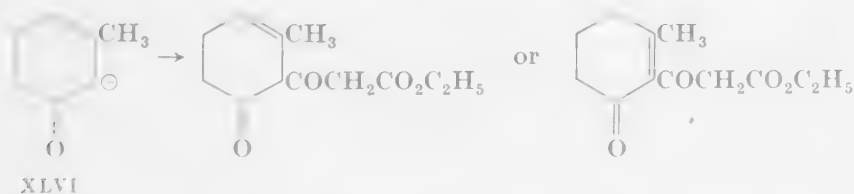
This mechanism was advanced as a parallel to the Holden-Lapworth formulation, but with a cyclohexanone rather than a cyclobutanone intermediate because formation of a para bridge where possible (as in this instance) is more favorable than the alternative XLIII.



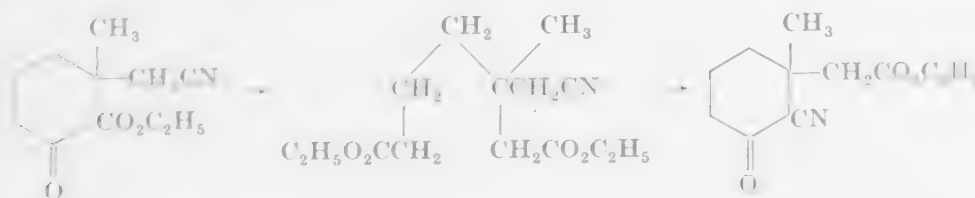
However, the suggestion has recently been made⁶³ that a para-bridged intermediate may not be formed in such instances. Instead the expected product of the abnormal Michael reaction, XLIV, may be first produced, and this may undergo ethanolysis (reverse Dieckmann) to give the *open-chain* triester XLV, which then cyclizes (in a known reaction) to XXXIX.



In any case, it has been shown that the normal adduct XLI is not the precursor of XXXIX, since the latter is produced in higher yield from 3-methyl-2-cyclohexenone and diethyl malonate than from XLI.⁶³ It is suggested,⁶³ as in the case mentioned above, that the first step is an ester condensation, either at position 6 (which would involve subsequent para bridging) or more probably at position 2 via the anion XLVI.



This explanation is based on a parallel with the mechanism for the reaction of 3-methyl-2-cyclohexenone with ethyl cyanoacetate, which was outlined on the basis of detailed evidence as involving the following succession of intermediates:



Stereochemistry of the Michael Condensation

Little is known about the steric course of the Michael condensation, although the formation of asymmetric carbon atoms in open-chain products and the possibility of *cis-trans* isomerism in allylic adducts

raise a number of stereochemical problems. The formation of diastereomeric adducts has often been noted, e.g., with the following reactants: benzylideneacetone and dimethyl malonate;⁷¹ benzylideneacetophenone and benzyl cyanide;⁷² diethyl succinate;⁷³ and *p*-tolyl benzyl sulfone;⁷⁴ α -benzylidenepropiophenone and dimethyl malonate;^{75,76} ethyl cinnamate and diethyl methylmalonate;^{50,77} ethyl β -isopropylacrylate and ethyl cyanoacetate;⁷⁸ ethyl cinnamate and ethyl cyanoacetate;^{79,80} ethyl phenylacetate;^{81,82} or benzyl cyanide;^{27,83,84} cinnamionitrile and *m*-aminobenzyl cyanide;²⁷ 2-nitro-2-butene and benzyl cyanide;⁸⁵ 2-nitro-1-phenyl-1-propene and diethyl malonate;⁸⁶ α -nitrostilbene and diethyl malonate;⁸⁶ and 3-cyano-1,2,5,6-tetrahydropyridine and diethyl malonate.⁸⁷

In the condensation of ethylideneacetone with 7-chloro-4,6-dimethoxycoumaran-3-one, two possible isomers are formed simultaneously;⁸⁸ a similar result was obtained in the condensation with the chlorine-free analog. The reaction between 4-methylcyclohexanone and methyl isopropenyl ketone also leads to two stereoisomeric forms of 3,6-dimethyl-9-hydroxy-2-decalone.⁸⁹

The reaction pairs benzylideneacetophenone-benzyl cyanide⁷² and α -benzylidenepropiophenone-dimethyl malonate^{75,76} represent two different ways in which asymmetric carbon atoms can be formed as a result of a Michael condensation. In the adduct XLVII the α - and β -carbon atoms of the acceptor become asymmetric; in the adduct XLVIII the β -carbon atom of the acceptor and the carbon atom of the donor molecule that is linked to the acceptor become the centers of asymmetry. In view of the undoubted ability of the alkaline condensing agent to invert configuration around carbon atoms substituted as in $-\text{CH}(\text{CH}_3)(\text{COC}_6\text{H}_5)$,

⁷¹ Qudrat-I-Khuda, *J. Indian Chem. Soc.*, **8**, 215 (1931) [*C.A.*, **26**, 123 (1932)].

⁷² Kohler and Allen, *J. Am. Chem. Soc.*, **46**, 1522 (1924).

⁷³ Stobbe, *Ann.*, **314**, 111 (1901).

⁷⁴ Connor, Fleming, and Clayton, *J. Am. Chem. Soc.*, **58**, 1386 (1936).

⁷⁵ Kohler, *Am. Chem. J.*, **46**, 474 (1911).

⁷⁶ Kohler and Davis, *J. Am. Chem. Soc.*, **41**, 992 (1919).

⁷⁷ Michael and Ross, *J. Am. Chem. Soc.*, **53**, 1150 (1931).

⁷⁸ Howles, Thorpe, and Udall, *J. Chem. Soc.*, **77**, 942 (1900).

⁷⁹ Carter and Lawrence, *Proc. Chem. Soc.*, **16**, 178 (1900).

⁸⁰ Avery and McGrew, *J. Am. Chem. Soc.*, **57**, 208 (1935).

⁸¹ Badger, Campbell, and Cook, *J. Chem. Soc.*, **1949**, 1084.

⁸² Borsche, *Ber.*, **42**, 4496 (1909).

⁸³ Avery, *J. Am. Chem. Soc.*, **50**, 2512 (1928).

⁸⁴ Avery and McDole, *J. Am. Chem. Soc.*, **30**, 1423 (1908).

⁸⁵ Buckley, Hunt, and Lowe, *J. Chem. Soc.*, **1947**, 1504.

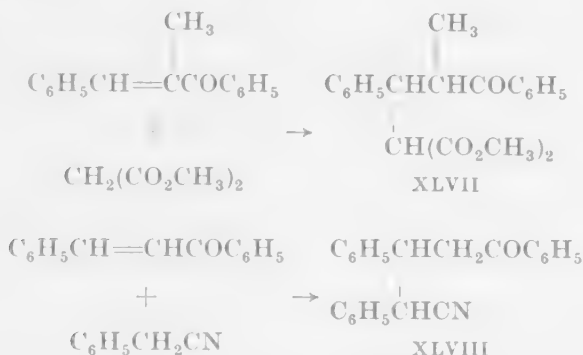
⁸⁶ Boberg and Schultze, *Chem. Ber.*, **88**, 74 (1955).

⁸⁷ Wohl and Losantsch, *Ber.*, **40**, 4698 (1907).

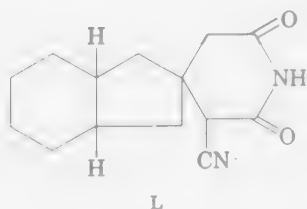
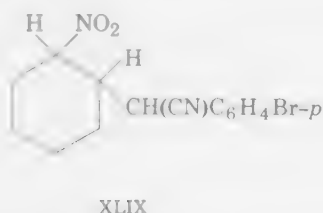
⁸⁸ MacMillan, Mulholland, Dawkins, and Ward, *J. Chem. Soc.*, **1954**, 429.

⁸⁹ Colonge, Dreux, and Kehlstadt, *Compt. rend.*, **238**, 693 (1954).

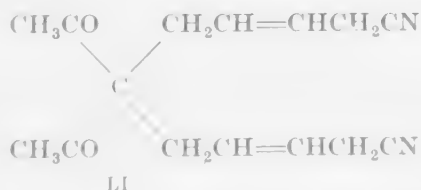
and $-\text{CH}(\text{CN})\text{C}_6\text{H}_5$, the product isolated must be an equilibrium mixture of all possible forms. The isolation of diastereomerides from product mixtures is then evidence that the forms involved are approximately equal energetically.



Both *cis* and *trans* forms arise in the condensation of 1-nitrocyclohexene with *p*-bromobenzyl cyanide to XLIX,⁸⁵ whereas only one isomer (L) is formed from *cis*-2-hydrindylideneacetonitrile and cyanoacetamide.⁹⁰



One unsaturated Michael adduct LI appears in *cis* and *trans* isomeric forms; this is the product of the reaction between acetylacetone and 2 moles of 1-cyanobutadiene.⁹¹



When only one adduct is formed, the determination of its configuration is usually difficult due to the lack of reference compounds of established configuration. However, it has been proved that the bicyclic compounds formed from acyl- or carbalkoxy-cyclohexenes frequently, if not generally, have the *trans* configuration. This applies to the following cases: ethyl cyclopentanecarboxylate with ethyl cyanoacetate or diethyl malonate

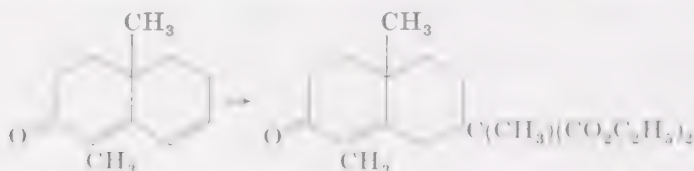
⁹⁰ Kandiah, *J. Chem. Soc.*, **1931**, 922.

⁹¹ Charlsh, Davies, and Rose, *J. Chem. Soc.*, **1948**, 232.

(*trans* only);⁹² acetylcyclohexene and ethyl acetoacetate (*trans* only);⁹³ acetylcyclohexene and diethyl malonate (*cis* and *trans*);⁹⁴⁻⁹⁶ 2-methyl-1-butyrylcyclohexene and diethyl malonate (*trans* only);⁹⁶ 2,6-dimethyl-butyrylcyclohexene and diethyl malonate (*trans* only);⁹⁶ vinyl cyclohexenyl ketone and diethyl malonate (*trans* only);¹⁰⁰ 4-methoxy- and 3,4-methylenedioxy-benzalacetophenone and 3-methylcyclohexanone (*cis* and *trans*);^{100a} methyl isopropenyl ketone and 3- and 4-methylcyclohexanone (*cis* and *trans*);¹⁰¹ and (±)-dihydrocarvone and 1-diethylamino-3-pentanone methiodide (*cis* and *trans*).¹⁰²

Isomers have also been formed in the self-condensation of 1-acetyl-1-cyclohexene^{97,98} and in the condensation of 1-acetyl-1-cyclohexene with 1-tetralone.⁹⁹

In the total synthesis of santonin,¹⁰³ use was made of the fact that the Michael condensation of diethyl methylmalonate and 1,10-dimethyl-2-oxo-2,3,4,5,6,10-hexahydronaphthalene introduces the side chain so that



it is *cis* to the methyl group at C₁₀.¹⁰⁴ An analogous observation has been made for 3,5-cholestadien-7-one.

Cis addition is observed in the addition of diethyl malonate, diethyl methylmalonate, and ethyl acetoacetate to methyl bicyclo[2.2.1]hepta-2,5-diene-2-carboxylate^{104a} and in the addition of diethyl malonate to ethyl 1-cyclohexene-1-carboxylate.^{104b}

⁹² Cook and Linstead, *J. Chem. Soc.*, **1934**, 956.

⁹³ Barrett, Cook, and Linstead, *J. Chem. Soc.*, **1935**, 1065.

⁹⁴ Chuang and Tien, *Ber.*, **69**, 25 (1936).

⁹⁵ Kon and Qudrat-I-Khuda, *J. Chem. Soc.*, **1926**, 3071.

⁹⁶ Ruzicka, Koolhaas, and Wind, *Helv. Chim. Acta*, **14**, 1151 (1931).

⁹⁷ Jones and Koch, *J. Chem. Soc.*, **1942**, 393.

⁹⁸ Rapson and Robinson, *J. Chem. Soc.*, **1935**, 1285; Hawthorne and Robinson, *ibid.* **1936**, 763.

⁹⁹ Peak and Robinson, *J. Chem. Soc.*, **1936**, 759.

¹⁰⁰ Downes, Gill, and Lions, *J. Am. Chem. Soc.*, **72**, 3464 (1950); *Australian J. Sci.*, **10**, 147 (1948).

^{100a} Kohler, Graustein, and Merrill, *J. Am. Chem. Soc.*, **44**, 2536 (1922).

¹⁰¹ Colonge, Dreux, and Kehlstadt, *Bull. soc. chim. France*, **1954**, 1404.

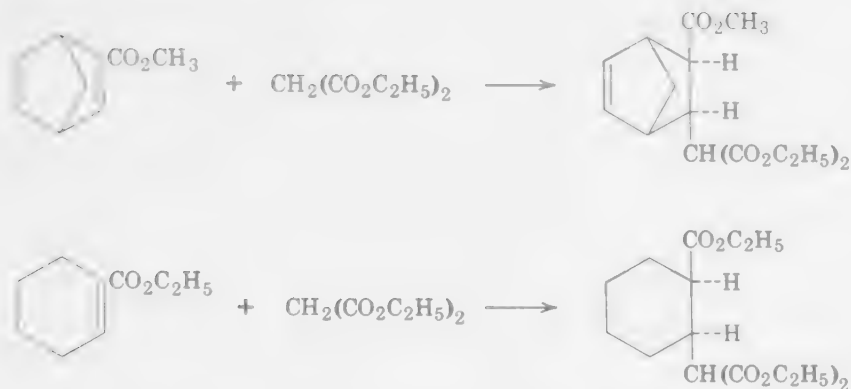
¹⁰² Abe and McQuillin, *J. Chem. Soc.*, **1955**, 2423.

¹⁰³ Abe, Harukawa, Ishikawa, Miki, and Sami, *Proc. Japan Acad.*, **30**, 116, 119 (1954) [*C.A.*, **49**, 14715 (1955)].

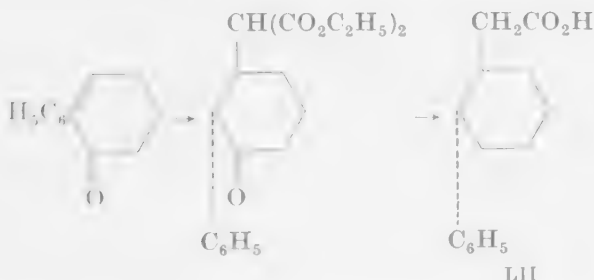
¹⁰⁴ Corey, *J. Am. Chem. Soc.*, **77**, 1044 (1955).

^{104a} Alder and Wirtz, *Ann.*, **601**, 138 (1956).

^{104b} Helfer, *Helv. Chim. Acta*, **9**, 814 (1926). Other interesting observations of this type are reported by Johnson, *Chem. & Ind. (London)*, **1956**, 167, and by Wettstein, *Heusler, Festschriften zum 70. Geburtstag*, **1956**, 40, 311 (1956).



A tendency for *trans* addition is evident in the Michael condensation of 2-aryl-2-cyclohexen-1-ones. Here it has been shown with diethyl malonate that a *trans* compound is obtained, for the product could be related to the known *trans*-2-phenylcyclohexylacetic acid (LII).^{105,106}



It has further been demonstrated that the addition of dibenzyl malonate to 4-phenyl- or 5-phenyl-2-cyclohexenone¹⁰⁷ and of methyl nitroacetate to 2-phenyl-2-cyclohexenone takes the same steric course.¹⁰⁸

SCOPE AND LIMITATIONS

Donors

All of the donor molecules appearing in Tables I-XXI are collected in Table XXII. In the almost complete absence of kinetic studies of the Michael condensation, an exact comparison of the compounds acting as donors in the condensation is impossible. However, in some cases in which the donor contains two active hydrogen atoms, the efficacy of the

¹⁰⁵ Bachmann and Fornfeldt, *J. Am. Chem. Soc.*, **72**, 5529 (1950).

¹⁰⁶ Ginsburg and Pappo, *J. Chem. Soc.*, **1951**, 938.

¹⁰⁷ Bergmann and Szmuszkowicz, *J. Am. Chem. Soc.*, **75**, 3226 (1953).

¹⁰⁸ Ginsburg and Pappo, *J. Chem. Soc.*, **1953**, 1524.

activating groups can be compared directly. For example, two carboethoxy groups activate hydrogen more than one carboethoxy¹⁰⁹ or one aldehyde group,¹¹⁰ but one carbonyl group is more effective than one carboethoxy group.¹¹¹ The groups $\text{CH}(\text{CH}_3)$ and $\text{CH}(\text{C}_6\text{H}_5)$ have greater activating power than a methylene group,¹¹²⁻¹¹⁵ and a nitro group is a more powerful activator than a carboethoxy¹¹⁶ or an alkylsulfonyl group.¹¹⁷ It also appears to be generally true that unsaturated ketones are more reactive than nitriles and nitriles more than esters, and that α,β -unsaturated sulfones are least reactive.¹¹⁸⁻¹²² The behavior of methyl β -cyanoethyl ketone in Michael additions¹²³ confirmed the stronger activating influence of a carbonyl group as opposed to a nitrile group. Recent work¹²⁴ has shown that the phosphonate group $-\text{PO}(\text{OR})_2$ also activates hydrogen atoms on the adjoining carbon atom. Like the nitro and sulfoxide functions, it also activates neighboring double bonds to act as acceptors (see Table XXI).

Though one would expect the reactivity of a donor to be related to the degree of enolization in the reaction environment, no simple relationship was found between reactivity and the tendency of the donor to enolize in the pure state.¹²⁵ Likewise, the reactivity of a methylene or methine group toward a Grignard reagent (Zerewitinoff test) does not appear to parallel its activity as a donor in the Michael reaction.¹²⁶

Generally speaking, one would expect that the degree to which the Michael reaction takes place, as well as its rate, should be importantly influenced by the acidity of the donor and the polarity of the carbon-carbon double bond in the acceptor. As to the former, the acidity of the

hydrogen atom in the group RCH decreases in the following sequence

¹⁰⁹ Friedmann, *J. prakt. Chem.*, [2], **146**, 79 (1936).

¹¹⁰ Moe, Warner, and Buckley, *J. Am. Chem. Soc.*, **73**, 1062 (1951).

¹¹¹ Hill, *Am. Chem. J.*, **24**, 1 (1900).

¹¹² Bachmann and Wick, *J. Am. Chem. Soc.*, **72**, 3388 (1950).

¹¹³ Boekelheide, *J. Am. Chem. Soc.*, **69**, 790 (1947).

¹¹⁴ Frank and Pierle, *J. Am. Chem. Soc.*, **73**, 724 (1951).

¹¹⁵ Wilds, Ralls, Wildman, and McCaleb, *J. Am. Chem. Soc.*, **72**, 5794 (1950).

¹¹⁶ Leonard, Felley, and Nicolaides, *J. Am. Chem. Soc.*, **74**, 1700 (1952).

¹¹⁷ Buckley, Elliott, Hunt, and Lowe, *J. Chem. Soc.*, **1947**, 1505.

¹¹⁸ Truce and Wellisch, *J. Am. Chem. Soc.*, **74**, 2881 (1952).

¹¹⁹ Henecka, *Chem. Ber.*, **81**, 197 (1948).

¹²⁰ Henecka, *Chem. Ber.*, **82**, 41 (1949).

¹²¹ Henecka, *Chem. Ber.*, **82**, 104 (1949).

¹²² Henecka, *Chem. Ber.*, **82**, 112 (1949).

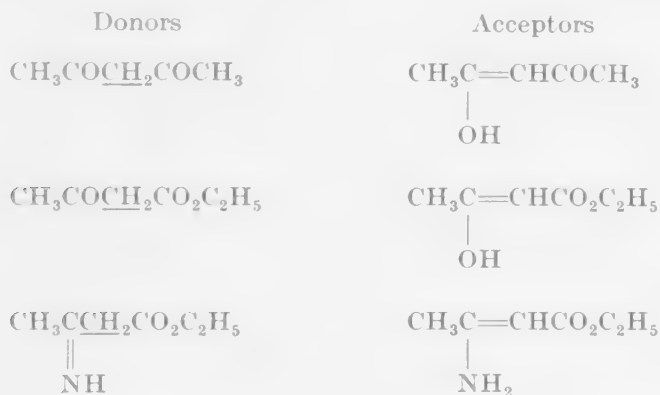
¹²³ Chem. Werke Huels, Ger. pat. 811,231 [C.A., **47**, 11234 (1953)].

¹²⁴ Pudovik and Lebedeva, *Zhur. Obshchei Khim.*, **22**, 2128 (1952) [C.A., **48**, 564 (1954)].

¹²⁵ Connor and Andrews, *J. Am. Chem. Soc.*, **56**, 2713 (1934).

¹²⁶ McAlpine and Ongley, *Anal. Chem.*, **27**, 55 (1955).

$R = NO_2 > SO_3R > CN > CO_2R > CHO > COR$.¹²⁷ As to the latter, the electromeric effects of the activating groups which produce polarity in the double bond diminish in the sequence $CHO > COR > CN > CO_2R > NO_2$. Through possession of appropriate combinations of these groups certain substances, e.g., β -diketones, β -keto esters or ethyl β -aminocrotonate, can act either as donors or acceptors.



Reactions with Cyclopropane Derivatives

A few cyclopropane derivatives have been observed to participate in the Michael condensation. In the reaction of ethyl 1-cyanocyclopropane-1-carboxylate (LIII) with both ethyl cyanoacetate¹²⁸ and diethyl malonate¹²⁹ ring scission occurs.¹²⁹⁻¹³³ The intermediates LIV and LV cyclize to the corresponding cyclopentanoneimide derivatives LVI and LVII; subsequent elimination of the cyano and the second carboxy group, respectively, leads to diethyl cyclopentanone-2,5-dicarboxylate (LVIII). In the analogous reaction between diethyl malonate and diethyl cyclopropane-1,1-dicarboxylate, the same cyclopentanone derivative (LVIII) formed via tetraethyl butane-1,1,4,4-tetracarboxylate can be isolated.^{130,134} The similarity between a double bond and the cyclopropane ring illustrated by this reaction is supported by other

¹²⁷ Arndt, Scholz, and Frobel, *Ann.*, **521**, 111 (1936).

¹²⁸ Thorpe, *J. Chem. Soc.*, **95**, 1901 (1909).

¹²⁹ Mitchell and Thorpe, *J. Chem. Soc.*, **97**, 997 (1910).

¹³⁰ Bone and Perkin, Jr., *J. Chem. Soc.*, **67**, 108 (1895).

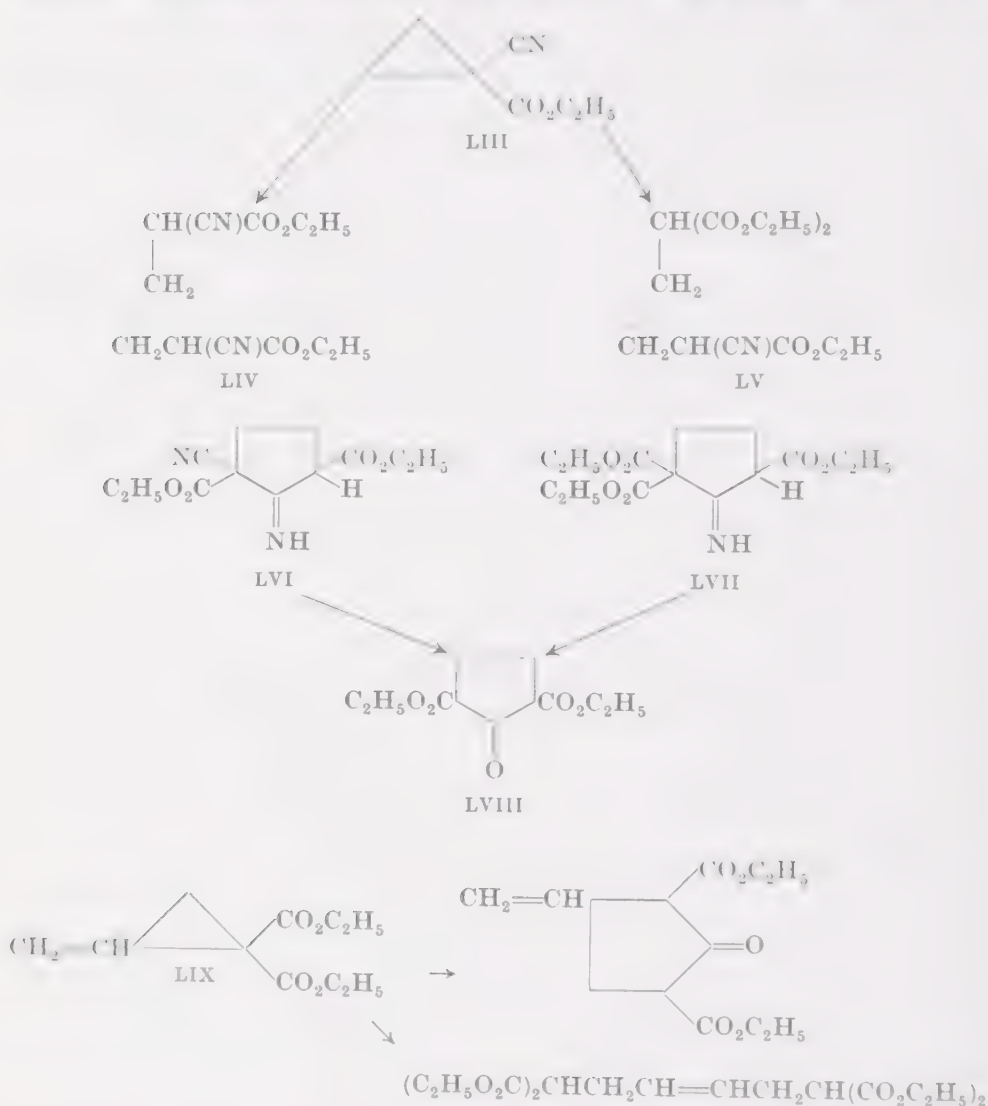
¹³¹ Cf. Fittig and Roeder, *Ann.*, **227**, 13 (1885).

¹³² Cf. Best and Thorpe, *J. Chem. Soc.*, **95**, 697, 699 (1909).

¹³³ Radulescu, *Ber.*, **44**, 1018 (1911).

¹³⁴ Kierstead, Linstead, and Weedon, *J. Chem. Soc.*, **1952**, 3616.

evidence,¹³⁵⁻¹⁴⁴ particularly by the recent experiments showing that the enolate of diethyl malonate undergoes a Michael reaction with diethyl 2-vinylcyclopropane-1,1-dicarboxylate (LIX);¹³⁴ this partly follows the



¹³⁵ Cf. Klotz, *J. Am. Chem. Soc.*, **66**, 88 (1944); Roberts and Green, *ibid.*, **68**, 214 (1946); Rogers, *ibid.*, **69**, 2544 (1947); cf. ref. 137.

¹³⁶ Kierstead, Linstead, and Weedon, *J. Chem. Soc.*, **1952**, 3610.

¹³⁷ Mariella, Peterson, and Ferris, *J. Am. Chem. Soc.*, **70**, 1494 (1948).

¹³⁸ Smith and Rogier, *J. Am. Chem. Soc.*, **73**, 3831 (1951).

¹³⁹ Smith and Rogier, *J. Am. Chem. Soc.*, **73**, 3840 (1951).

¹⁴⁰ Mariella and Raube, *J. Org. Chem.*, **18**, 282 (1953).

¹⁴¹ Greenfield, Friedel, and Orchin, *J. Am. Chem. Soc.*, **76**, 1258 (1954).

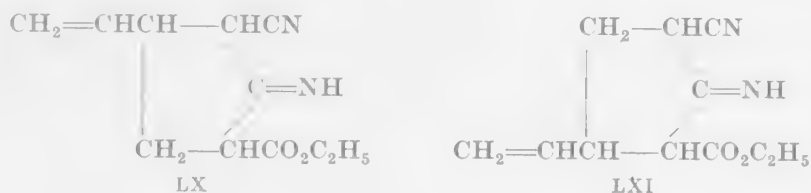
¹⁴² Perold, *J. S. African Chem. Inst.*, **6**, 22 (1953) [*C.A.*, **48**, 4314 (1954)].

¹⁴³ Eastman, *J. Am. Chem. Soc.*, **76**, 4115 (1954).

¹⁴⁴ Eastman and Selover, *J. Am. Chem. Soc.*, **76**, 4118 (1954).

above scheme, but partly takes place at the ends of the "conjugated" system. Both reactions occur also in $\alpha,\beta,\gamma,\delta$ doubly unsaturated carboxylic acid derivatives (see p. 237).

A similar study has been made¹⁴⁵ of the reaction of ethyl cyanoacetate with ethyl 1-cyano-2-vinylcyclopropane-1-carboxylate, synthesized *in situ* from *trans*-1,4-dibromo-2-butene and ethyl cyanoacetate. The product, obtained in 30% yield, was a mixture of the two cyclopentane derivatives LX and LXI.



The System $\text{C}=\text{C}-\text{C}=\text{N}$

The system $\text{C}=\text{C}-\text{C}=\text{N}$ behaves like the system $\text{C}=\text{C}-\text{C}=\text{O}$ in the Michael reaction. The most extensive studies, on the addition of reactive methylene compounds to quinone imides, have been summarized.^{145a} selected examples are given in Table IX.

2-Vinylpyridine and 4-vinylpyridine are suitable acceptors for the Michael reaction (Table XXI). Analogously, phenanthridine-9-carboxaldehyde reacts with 9-methylphenanthridine (LXII) to give 1,2,3-tri-(9-phenanthridyl)propane (LXIII),¹⁴⁶ undoubtedly as shown on page 208. The formation of diethyl 4-methyl-5-acetylpyridine-2,6-dicarboxylate (LXVIII) from ethyl acetylpyruvate (LXIV) and ammonia¹⁴⁷ appears to result from reaction of part of the ester with ammonia to give the imine of its enolic form and a subsequent Michael condensation between the latter and the keto form of the original ester or its imine.

In this connection, it should be mentioned that Schiff bases of the benzylideneaniline type (but not ketone anils) add, for example, ethyl acetoacetate,¹⁴⁸⁻¹⁵⁰ ethyl oxaloacetate,^{148,151} diethyl malonate,¹⁵² ethyl

¹⁴⁵ Kierstead, Linstead, and Weedon, *J. Chem. Soc.*, **1953**, 1799.

^{145a} Adams and Reifschneider, *Bull. soc. chim. France*, **1958**, 23.

¹⁴⁶ Caldwell, *J. Chem. Soc.*, **1952**, 2035.

¹⁴⁷ Mumm and Bergell, *Ber.*, **45**, 3040 (1912).

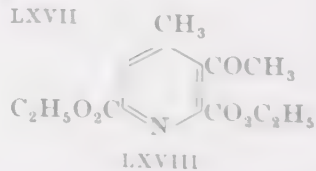
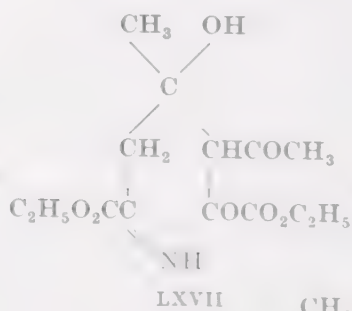
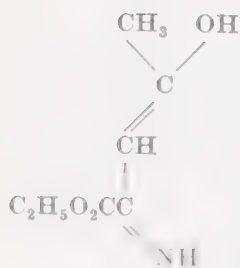
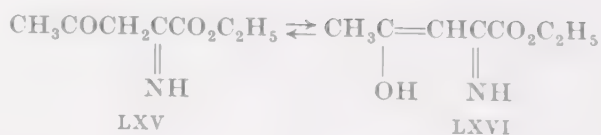
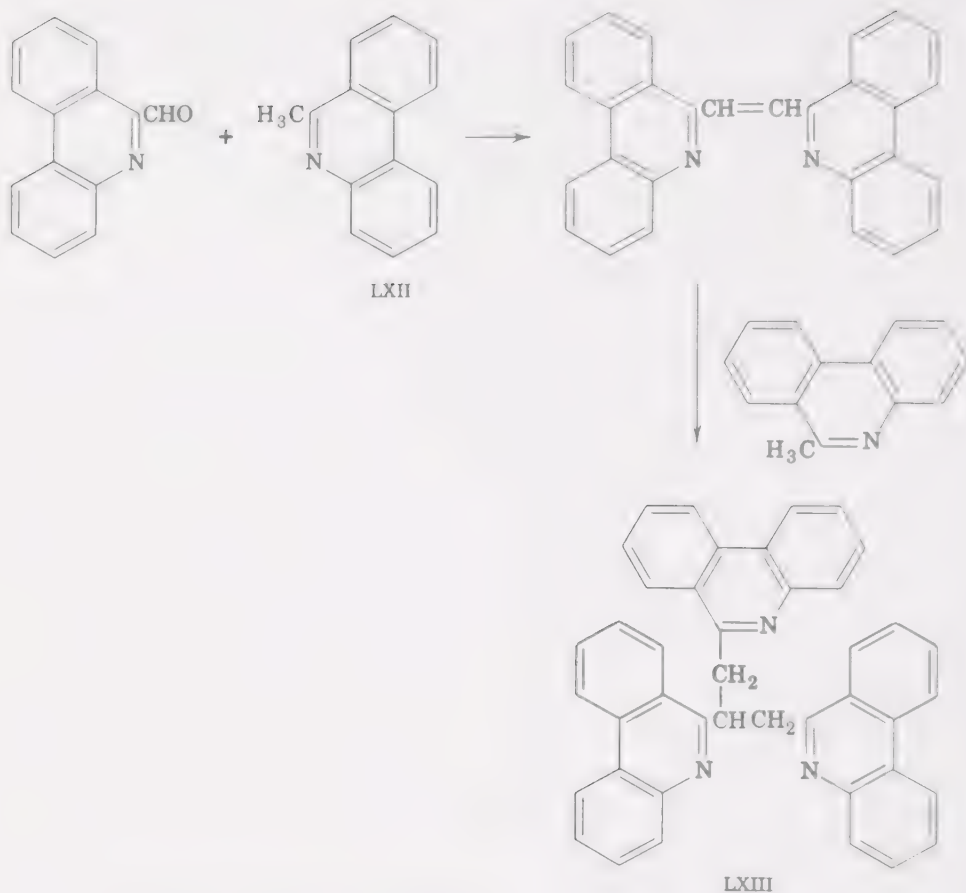
¹⁴⁸ Schiff and Bertini, *Ber.*, **30**, 601 (1897).

¹⁴⁹ Schiff, *Ber.*, **31**, 205 (1898).

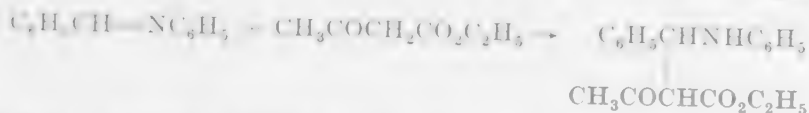
¹⁵⁰ Schiff, *Ber.*, **31**, 601 (1898).

¹⁵¹ Philpott and Jones, *J. Chem. Soc.*, **1938**, 337.

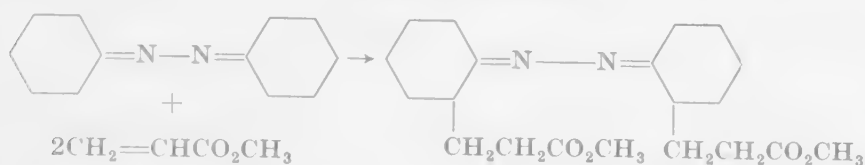
¹⁵² Betti, *Gazz. chim. ital.*, **30**, II, 301 (1900).



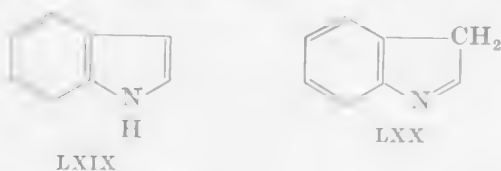
cyclopentanone-2-carboxylate,¹⁵¹ ethyl cyanoacetate, malonamide, cyanoacetamide,¹⁵³ and ethyl nitroacetate,¹⁵⁴ according to the following scheme.



The C=N group in Schiff bases and azines appears to behave as a carbonyl group, for these compounds can serve as donors. Examples are furnished by the Schiff bases of aliphatic aldehydes and ketones and of cycloalkanones which can be cyanoethylated in the α position to the carbon atom of the azomethine group.^{154a} The reaction can be illustrated with cyclohexanone azine and methyl acrylate.^{154b}



Also, one can at least formally explain the reaction of the 3-hydrogen atom of indole (LXIX) with 1-ethylthiomethyl-2-naphthol¹⁵⁵ by the formulation of indole as the tautomeride LXX. An analogous reaction



is that between indolylmagnesium bromide and compounds of the ω -nitrostyrene type.¹⁵⁶

Acceptors

α,β -Ethylenic Aldehydes (Table I). The condensation of α,β -ethylenic aldehydes (acrolein, crotonaldehyde, cinnamaldehyde) with suitable acid derivatives^{119,157-162} (malonates, cyanoacetates, ethyl

¹⁵² Lazzareschi, *Gazz. chim. ital.*, **67**, 371 (1937).

¹⁵⁴ Dornow and Frese, *Ann.*, **578**, 122 (1952).

^{154a} Krimm, U.S. pat. 2,768,962 [C.A., **51**, 6684 (1957)].

^{154b} Haring and Wagner-Juarez, *Helv. Chim. Acta*, **40**, 852 (1957).

¹⁵⁵ Poppelsdorf and Holt, *J. Chem. Soc.*, **1954**, 4094.

¹⁵⁶ Noland, Christensen, Sauer, and Dutton, *J. Am. Chem. Soc.*, **77**, 456 (1955).

¹⁵⁷ Farmer and Mehta, *J. Chem. Soc.*, **1931**, 2561.

¹⁵⁸ Standinger and Ruzicka, *Helv. Chim. Acta*, **7**, 442 (1924).

¹⁵⁹ Warner and Moe, *J. Am. Chem. Soc.*, **70**, 3470 (1948).

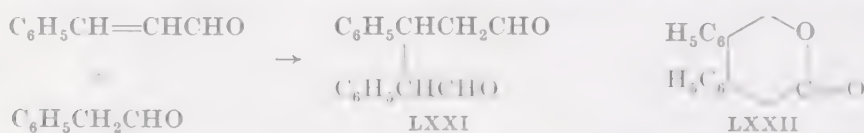
¹⁶⁰ Warner and Moe, *J. Am. Chem. Soc.*, **71**, 2756 (1949); U.S. pat. 2,498,352 [C.A., **43**, 7595 (1949)].

¹⁶¹ Warner and Moe, U.S. pat. 2,506,050 [C.A., **44**, 8946 (1950)].

¹⁶² Cope and Synerholm, *J. Am. Chem. Soc.*, **72**, 5228 (1950).

cyclohexanone-2-carboxylate) leads to derivatives of δ -aldehyde acids. Alkyl substitution in the α position does not appear to influence adversely the ability of the aldehydes to undergo Michael condensation; β substitution, on the other hand, alters the course of the reaction.^{157,158} (For further synthetic uses of the condensation products see p. 249.)

There are very few examples of condensations between α,β -ethylenic aldehydes and ketones or aldehydes. In the aldehyde- α,β -ethylenic aldehyde condensations secondary reactions regularly accompany the condensation.¹⁶³⁻¹⁶⁵ For example, the product to be expected from the interaction between cinnamaldehyde and phenylacetaldehyde, the dialdehyde LXXI, undergoes an intramolecular Cannizzaro reaction to yield δ -hydroxy- β,γ -diphenylvaleric acid, isolated as its lactone LXXII.



The "dimerization" of α,β -unsaturated aldehydes such as 2-ethyl-2-hexenal which takes place under the influence of aqueous-alcoholic alkali has been explained as a Michael reaction followed by intramolecular aldolization to yield a cyclic product.^{165a}

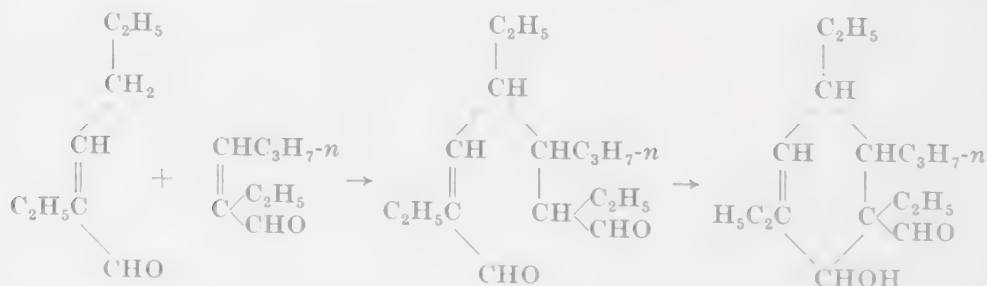


Table I includes some acceptors having a hydroxy (or alkoxy or amino) group attached to the double bond, i.e., they are the enolic forms of compounds that can also function as donors in the Michael reaction (see p. 205). All primary condensation products from donors that contain a C—NH group in the immediate vicinity of the reactive methylene group spontaneously cyclize with elimination of the hydroxy (alkoxy, amino) groups to yield pyridine derivatives.¹⁶⁶

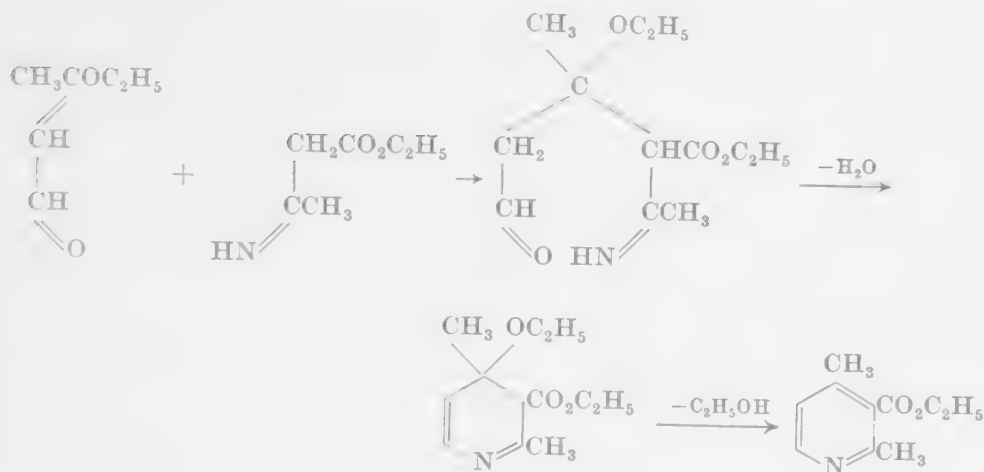
¹⁶³ Meerwein, *J. prakt. Chem.*, [2], **97**, 225 (1918).

¹⁶⁴ Hausermann, *Helv. Chim. Acta*, **34**, 1482 (1951).

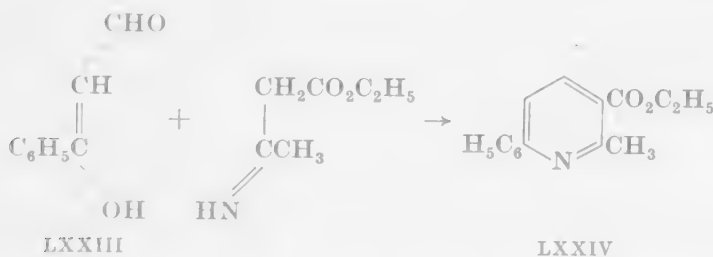
¹⁶⁵ Meerwein, *Ber.*, **53**, 1829 (1920).

^{165a} Nielsen, *J. Am. Chem. Soc.*, **79**, 2518, 2524 (1957).

¹⁶⁶ Dornow, *Ber.*, **72**, 1548 (1939). Compare, Baumgarten and Dornow, *Ber.*, **72**, 563 (1939).



However, the course of cyclization can sometimes vary. From benzoylacetalddehyde and ethyl β -aminocrotonate one does not obtain the expected ethyl 2-methyl-4-phenylpyridine-3-carboxylate, but the 6-phenyl isomer LXXIV.¹⁶⁷ This probably results from the reaction of benzoylacetalddehyde as β -hydroxycinnamic aldehyde (LXXIII) or as hydroxy-methyleneacetophenone.



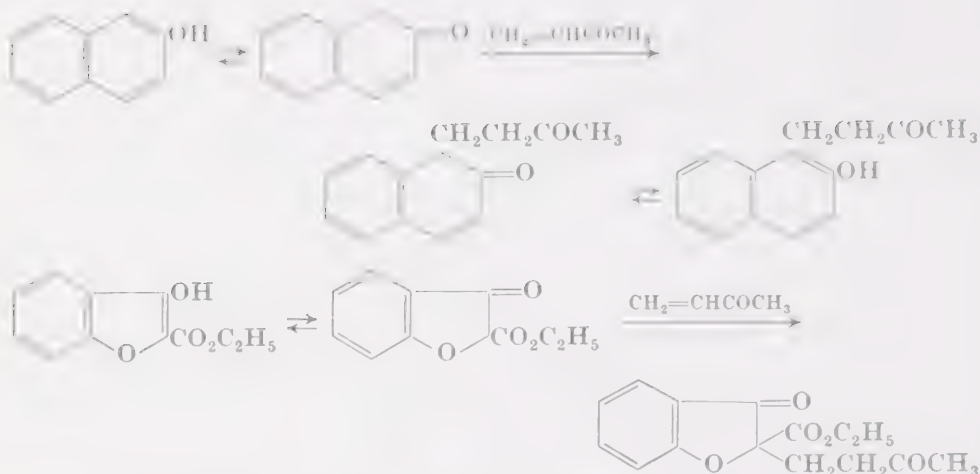
Aliphatic α,β -Ethylenic Ketones (Table II). The Michael condensation of aliphatic α,β -ethylenic ketones proceeds normally; the yields reported are often very high. The ease with which the ethylenic ketones undergo the condensation is exemplified by the fact that substances such as β -naphthal¹⁶⁸ or ethyl 3-hydroxy-4,5-benzofuran-2-carboxylate¹¹⁹ react with methyl vinyl ketone in their ketonic forms. The same is true for the reactions of 4-hydroxycoumarin with ethylideneacetone and methyl oxide, respectively.¹⁶⁹ Compare also the reaction of kojic acid with acrylonitrile.¹⁷⁰

¹⁶⁷ Spaeth and Burger, *Monatsh.*, **49**, 265 (1928).

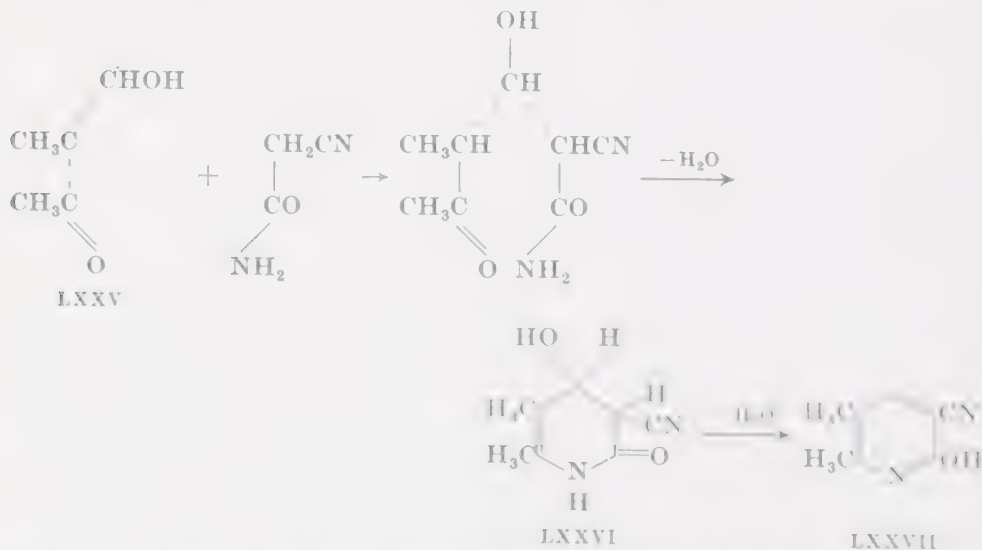
¹⁶⁸ Miller and Robinson, *J. Chem. Soc.*, **1934**, 1535.

¹⁶⁹ Ikawa, Stahmann, and Link, *J. Am. Chem. Soc.*, **66**, 902 (1944).

¹⁷⁰ Woods, *J. Am. Chem. Soc.*, **74**, 3959 (1952).



An example of the reaction of hydroxymethylene ketones is seen in the condensation of the methyl ethyl ketone derivative LXXV with cyanoacetamide (under the catalytic influence of pyridine or piperidine).^{171,172} The primary product cyclizes spontaneously and, dependent on the operating conditions, 2-keto-3-cyano-4-hydroxy-5,6-dimethyl-1,2,3,4-tetrahydropyridine (LXXVI) or its dehydration product, 2-hydroxy-3-cyano-5,6-dimethylpyridine (LXXVII), is obtained.

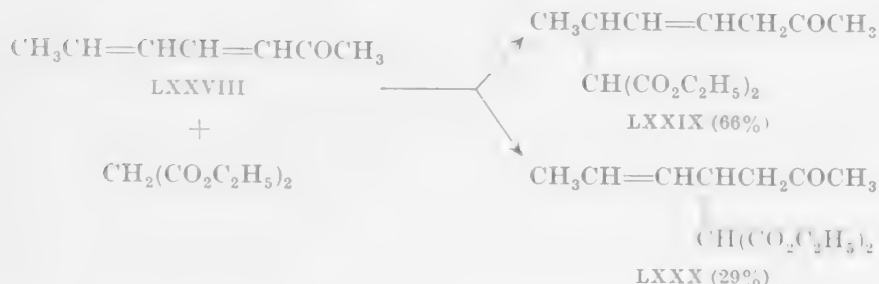


Mention should finally be made of the behavior of doubly unsaturated ketones. Of this group, two types have been somewhat cursorily investigated. Crotylideneacetone (LXXVIII) yields with diethyl malonate

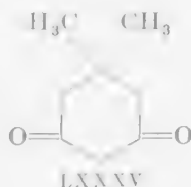
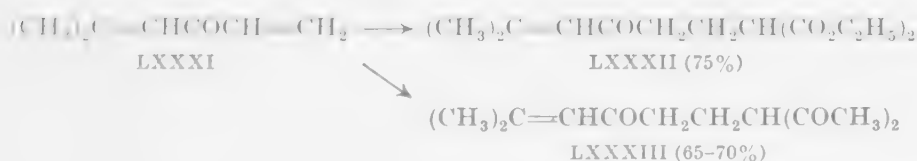
¹⁷¹ Tracy and Elderfield, *J. Org. Chem.*, **6**, 63 (1941).

¹⁷² Joshi, Kaushal, and Deshapande, *J. Indian Chem. Soc.*, **18**, 479 (1941) [*C.A.*, **36**, 4482 (1942)].

in the presence of sodium methoxide a mixture of two substances, of which the predominant one, LXXIX, results from 1,6 addition, the isomer LXXX from 1,4 addition.¹⁷³ 5-Methyl-1,4-hexadien-3-one (LXXXI) reacts under the influence of sodium methoxide, both with diethyl



malonate and acetylacetone at the less-substituted end of the molecule only, giving LXXXII and LXXXIII, respectively.¹⁷⁴ Phorone (LXXXIV) does not react analogously to LXXXI with diethyl malonate in alcoholic solution. Instead the product obtained, LXXXV,¹⁷⁵ is identical with that obtained from mesityl oxide.¹⁷⁶⁻¹⁷⁹ Apparently



phorone reverts to mesityl oxide more quickly than it reacts with the malonate, or the adduct formed suffers retrogression.

α,β -Acetylenic Ketones. Acetylenic ketones that contain the triple bond in the α,β position would be expected to give α,β -olefinic ketones in

¹⁷³ Farrer and Mehta, *J. Chem. Soc.*, **1931**, 1904.

¹⁷⁴ Nazarov and Terekhova; *Bull. acad. sci. U.R.S.S. Classe sci. chim.*, **1946**, 201 [*C.A.*, **42**, 7729 (1948)].

¹⁷⁵ Vorlaender and Guertner, *Ann.*, **304**, 1 (1899).

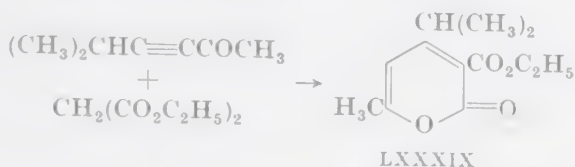
¹⁷⁶ Komppa, *Ber.*, **32**, 1421 (1899).

¹⁷⁷ Shriner and Todd, *Org. Syntheses Coll. Vol.* **2**, 200 (1950).

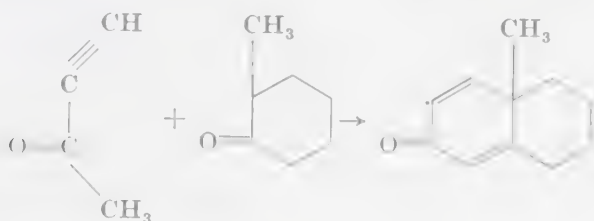
¹⁷⁸ Vorlaender, *Ann.*, **294**, 273 (1897).

¹⁷⁹ Vorlaender and Erig, *Ann.*, **294**, 302 (1897).

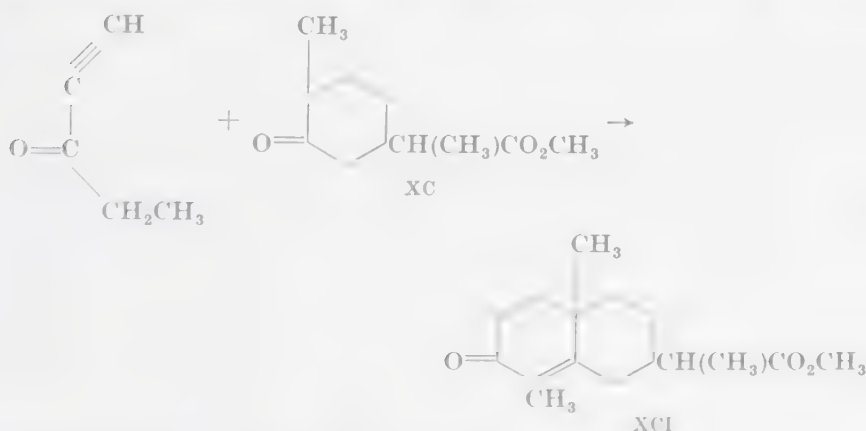
5-methyl-3-hexyn-2-one and diethyl malonate in the presence of a small quantity of sodium ethoxide 3-carbethoxy-4-isopropyl-6-methyl- α -pyrone (LXXXIX) was obtained in 59% yield.¹⁸⁵



Cyclization also takes place in the reaction between methyl ethynyl ketone and 2-methylcyclohexanone. Under the influence of sodium hydride, 2-keto-10-methyl-2,5,6,7,8,10-hexahydronaphthalene is formed.¹⁸⁶



In the Michael condensation between ethyl ethynyl ketone and the cyclohexanone derivative XC under the influence of sodium triphenylmethide, very low yields of XCI were obtained;¹⁸⁷ cf. refs. 188 and 189. As similar unsatisfactory results had been recorded in analogous



¹⁸⁵ Smith and Kelly, *J. Am. Chem. Soc.*, **74**, 3305 (1952).

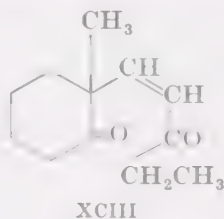
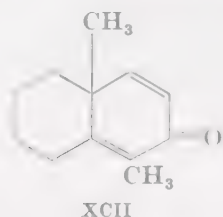
¹⁸⁶ Woodward and Singh, *J. Am. Chem. Soc.*, **72**, 494 (1950).

¹⁸⁷ Cleino and McQuillin, *J. Chem. Soc.*, **1952**, 3839.

¹⁸⁸ Gunstone and Tulloch, *J. Appl. Chem. London*, **4**, 291 (1954).

¹⁸⁹ Abe, Harukawa, Ishikawa, Miki, Sumi, and Toga, *Proc. Japan. Acad.*, **28**, 425 (1952) [*C. A.*, **48**, 1317 (1954)].

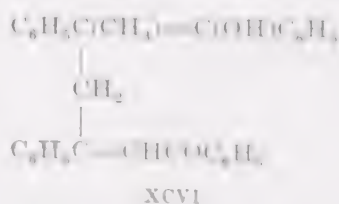
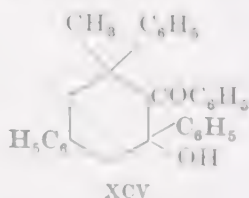
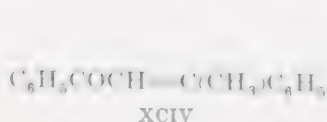
reactions,^{190,191} a systematic study of the reaction between 2-methylcyclohexanone (in the form of its metal enolates) and ethyl ethynyl ketone, formed in situ, was undertaken. However, β -chlorovinyl ethyl ketone, β -ethoxyvinyl ethyl ketone, and β -propionylvinylpyridinium chloride gave about the same yields as ethyl ethynyl ketone itself, and β -dimethylaminovinyl ethyl ketone did not react at all with the sodium enolate. Moreover, in addition to the expected 1,10-dimethyl-2-keto-2,5,6,7,8,10-hexahydronaphthalene (XCII), the open-chain product 2-methyl-2-(β -propionylvinyl)cyclohexanone (XCIII) was formed. A



considerable advantage was noted in use of the calcium or the lithium enolate of 2-methylcyclohexanone with β -chlorovinyl ethyl ketone; these gave yields of 12–14 and 20%, respectively, whereas the sodium enolate gave only 3–4%.

Aromatic α,β -Ethylenic Ketones (Tables III, IV). The introduction of aromatic radicals into the terminal positions of the system $C=C-C=O$ appears to increase its polar character and therefore its tendency to undergo the Michael condensation. Perhaps it is for this reason that a very large number of such reactions has been carried out. Those in which the ketone is unsaturated on only one side are summarized in Table III, in which the following order is observed: vinyl phenyl ketones, methyl styryl ketones, phenyl styryl ketones.

The unsaturated ketone dypnone (XCIV) undergoes self-condensation when treated with alkali. The product "dypnopinacol" has been given the formula XCV.¹⁹¹⁻¹⁹³ Although XCVI has been assumed to be an intermediate,^{191,192} it seems quite unlikely that the methyl group has a



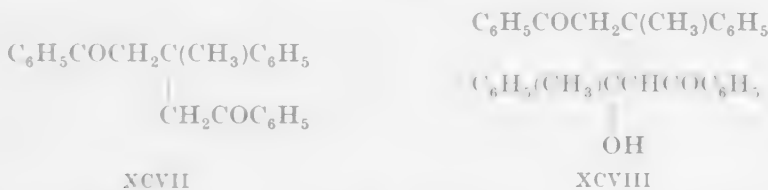
¹⁹⁰ Gunstone and Heggie, *J. Chem. Soc.*, **1952**, 1437.

¹⁹¹ Iwanow and Iwanow, *Ber.*, **76**, 988 (1943).

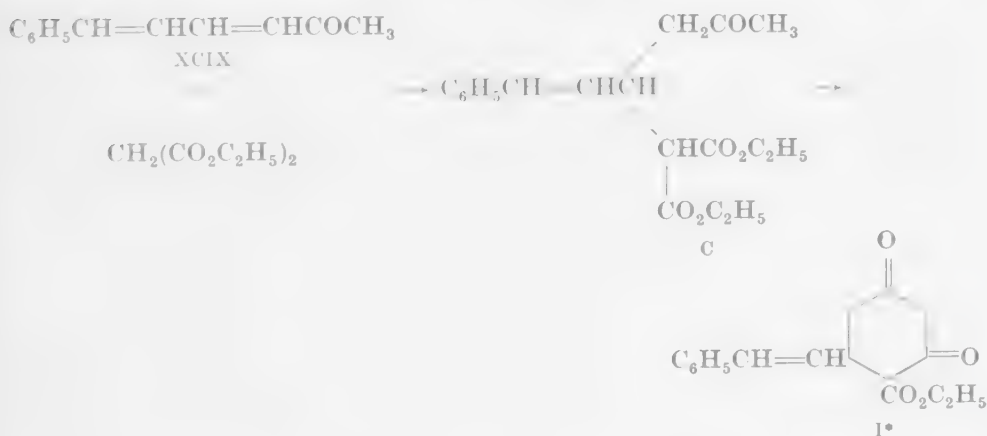
¹⁹² Iwanow and Iwanow, *Ber.*, **76**, 1148 (1943).

¹⁹³ Meerwein, *Ber.*, **77**, 229 (1944).

sufficiently reactive hydrogen to act as a donor. It is suggested by the authors that some of the dyponone is hydrolyzed to acetophenone by analogy with the known hydrolysis of mesityl oxide. Acetophenone then gives the diketone XCVII by Michael condensation; the diketone condenses with another molecule of acetophenone to yield the aldol XCVIII, which cyclizes normally to dyponpinacol.



Few doubly unsaturated ketones of the type $\text{C}_6\text{H}_5\text{CH}=\text{CHCH}=\text{CHCOR}$ appear to have been studied. When cinnamylideneacetone (XCIX) is treated with diethyl malonate and sodium ethoxide, 1,4 addition takes place. The primary product C cyclizes spontaneously, leading to



4-ethoxycarbony-5-styrylcyclohexane-1,3-dione (I).^{178,194,195} Cinnamylideneacetophenone also gives the 1,4 addition products II and III, respectively, with diethyl malonate and sodium ethoxide,¹⁹⁶ and with acetophenone



* Enumeration of formulas begins with I again after C to reduce the complexity of the numbers.

¹⁹⁴ Vorlaender, *Ber.*, **36**, 2339 (1903).

¹⁹⁵ Vorlaender and Groebel, *Ann.*, **345**, 155 (1906), especially p. 206.

¹⁹⁶ Vorlaender and Staudinger, *Ann.*, **345**, 155 (1906), especially p. 217.

and potassium hydroxide in ethanol.¹⁹⁷ This is in contradiction to the behavior of diethyl cinnamylidenemalonate (see p. 501), which undergoes 1,6 condensation. The adduct III from cinnamylideneacetophenone and acetophenone is accompanied by a product whose formation involves two moles of acetophenone. Condensation of cinnamylideneacetophenone with ethyl acetoacetate gave a substance $C_{28}H_{22}O_3$ of unelucidated structure.¹⁹⁶

Considerable attention has been paid to Michael condensations with doubly unsaturated ketones of the type $RCH=CHCOCH=CHR$, e.g., dibenzylideneacetone (IV)¹⁹⁸⁻²⁰⁰ and dicinnamylideneacetone (V).¹⁹⁸ The experimental material available, summarized in Table IV, shows that the two double bonds in dibenzylideneacetone undergo Michael condensation

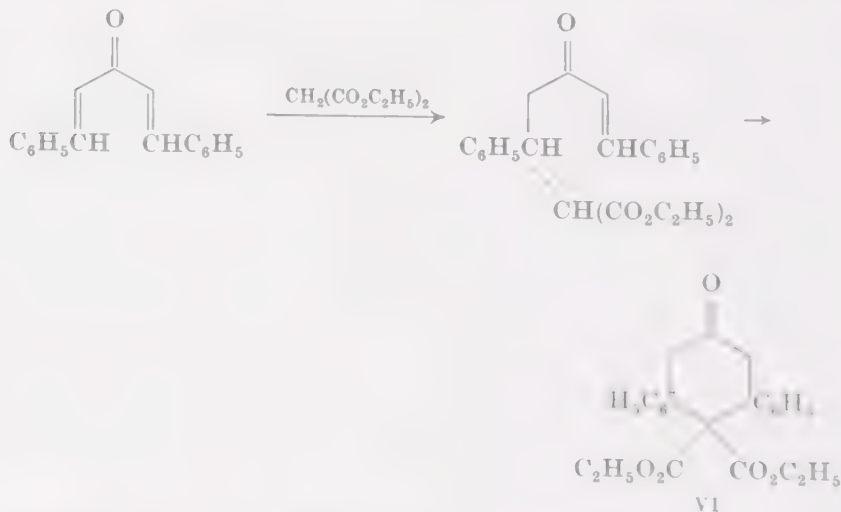


IV



V

independently of each other. If the donor contains two enolizable hydrogen atoms, there is often a secondary intramolecular step leading to a six-membered ring (VI).¹⁹⁸ Substances of the dicinnamylideneacetone type appear to undergo the Michael condensation by 1,4 (not 1,6) addition.¹⁹⁸



¹⁹⁷ Wittig and Kosack, *Ann.*, **529**, 167 (1937).

¹⁹⁸ Kohler and Dewey, *J. Am. Chem. Soc.*, **46**, 1267 (1924).

¹⁹⁹ Kohler and Helmkamp, *J. Am. Chem. Soc.*, **46**, 1018 (1924).

²⁰⁰ Marvel and Moore, *J. Am. Chem. Soc.*, **71**, 28 (1949).

It is of interest to compare the reactivity of the double bonds in unsymmetrically substituted dibenzylidene-acetones. In dibenzylidene-acetone, chlorine in the 2, 3, or 4 position²⁰¹ or a methoxyl group in the 4 position¹⁸⁸ deactivates the neighboring double bond so that Michael reaction occurs only on the side of the unsubstituted benzene ring. The chlorine atom in α -(3- or 4-chlorobenzylidene)- β -(4'-methoxybenzylidene)-acetone causes the reaction to take place on the double bond adjacent to the chlorinated nucleus. On the other hand, a hydroxyl group in the 2 or 4 position of the benzene nucleus has a stronger activating influence than a 2-methoxy group or a chlorine atom in the 3 or 4 position.²⁰²⁻²⁰⁴

It is noteworthy as well as surprising that ethyl acetoacetate condenses with α -(4-dimethylaminobenzylidene)- β -(2-hydroxybenzylidene)acetone, in the presence of *potassium* hydroxide as catalyst on the dimethylamino group side, whereas ethyl cyanoacetate with *sodium* hydroxide as catalyst adds to the side of the 2-hydroxyphenyl radical.²⁰⁵ The same difference is evident in two other cases listed in Table IV.

Heterocyclic α,β -Ethylenic Ketones (Tables V, VI). In view of the aromatic character of the furan system, α,β -ethylenic ketones containing the furyl group should behave like their phenyl analogs.^{121,206-210} This expectation is borne out by the examples in Table V. A characteristic difference, however, is the fact that almost no secondary cyclization or isomerization reactions take place. Table V also includes a few heterocyclic compounds not derived from furan.

Table VI lists a number of other heterocyclic α,β -ethylenic ketones, mostly of the acylcoumarin type.²¹¹⁻²¹³ Several reactions carried out with 2-(*p*-methoxybenzylidene)-4,5-benzo-2,3-dihydrofuran-3-one^{214,214a} and γ -pyrone are included.²¹⁵ The reaction of γ -pyrone and diethyl malonate is somewhat complicated, but it can be assumed that the first step is a Michael condensation to VII, which is followed by ring opening and

²⁰¹ Heilbron and Hill, *J. Chem. Soc.*, **1928**, 2863.

²⁰² Heilbron and Forster, *J. Chem. Soc.*, **125**, 2064 (1924).

²⁰³ Heilbron and Hill, *J. Chem. Soc.*, **1927**, 918.

²⁰⁴ Jennings and McGookin, *J. Chem. Soc.*, **1934**, 1741.

²⁰⁵ Heilbron, Forster, and Whitworth, *J. Chem. Soc.*, **127**, 2159 (1925).

²⁰⁶ Peak and Robinson, *J. Chem. Soc.*, **1937**, 1581.

²⁰⁷ Andrews and Connor, *J. Am. Chem. Soc.*, **57**, 895 (1935).

²⁰⁸ Drake and Gilbert, *J. Am. Chem. Soc.*, **52**, 4965 (1930).

²⁰⁹ Kloetzel, *J. Am. Chem. Soc.*, **69**, 2271 (1947).

²¹⁰ Turner, *J. Am. Chem. Soc.*, **73**, 1284 (1951).

²¹¹ Koelsch and Sundet, *J. Am. Chem. Soc.*, **72**, 1681 (1950).

²¹² Koelsch and Sundet, *J. Am. Chem. Soc.*, **72**, 1844 (1950).

²¹³ Sastri and Seshadri, *Proc. Indian Acad. Sci.*, **16A**, 29 (1942) [*C.A.*, **37**, 880 (1943)].

²¹⁴ Parnis, *Proc. Ind. Chem. Soc.*, **18**, 468 (1941) [*C.A.*, **36**, 4507 (1942)].

^{214a} Parnis, Shah, and Wheeler, *J. Univ. Bombay*, **10**, Part 3, 83 (1941) [*C.A.*, **36**, 4507 (1942)].

²¹⁵ R. B. Woodward, private communication.

recyclization. Elimination of one of the carboxyl groups makes possible the aromatization to form VIII.

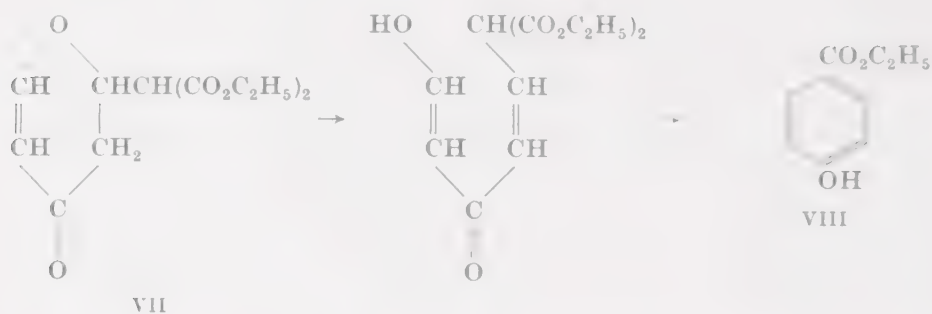
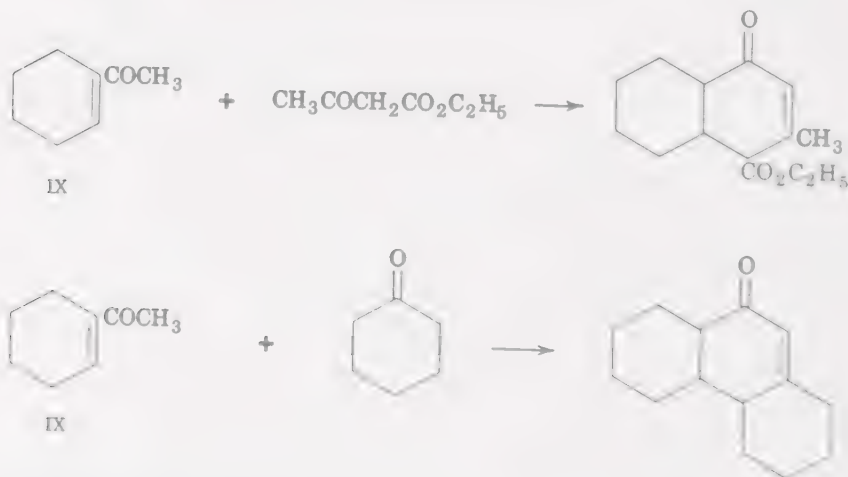


Table VI also includes the Michael condensation between rhodamine and alkylidenerhodanines. In this reaction, α,α -bis-(2-thio-4-ketotetrahydro-5-thiazolyl)alkanes are formed from rhodamine and aliphatic aldehydes.²¹⁶

Cycloalkenones and Acyl Cycloalkenes (Table VII). The Michael condensations of cycloalkenones and 1-acylcycloalkenes have been listed in a separate table (Table VII) in view of the importance of the products in the synthesis of hydroaromatic polycyclic substances related to the steroids and steroidal alkaloids.

The adducts obtained from acetylcycloalkenes^{83, 99, 216, 218} undergo intramolecular condensation to polycyclic ring systems, as exemplified in the accompanying reactions of 1-acetylcyclohexene (IX).^{93, 98}

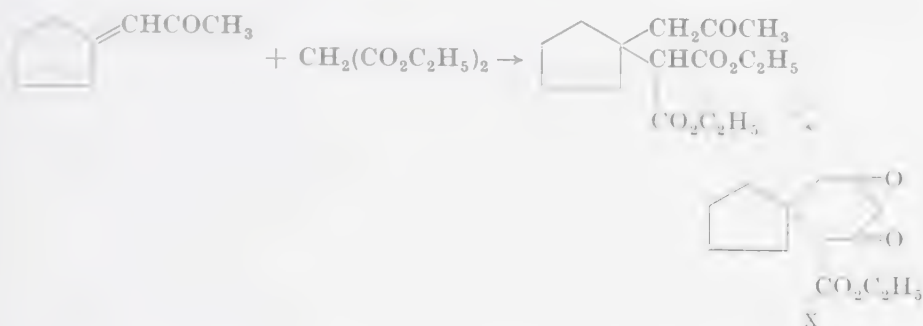


²¹⁶ Bradsher, Brown, and Grantham, *J. Am. Chem. Soc.*, **73**, 5377 (1951).

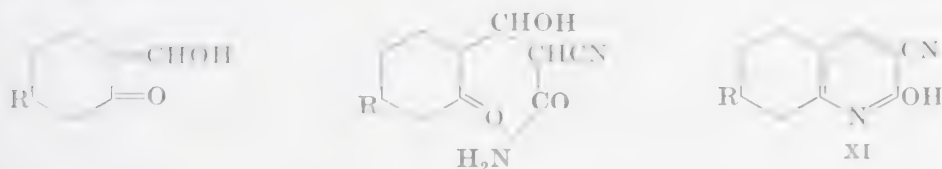
²¹⁷ Hawthorne and Robinson, *J. Chem. Soc.*, **1936**, 763.

²¹⁸ Hewett, *J. Chem. Soc.*, **1936**, 50.

Table VII further includes some cases in which cycloalkylideneacetones have been subjected to the Michael condensation.²¹⁹⁻²²³ Here, too, cyclization of the primary adduct is spontaneous as shown by the formation of X.²²¹ As in many other reactions, the remaining carbethoxyl group is often eliminated in the process.



Michael condensations with hydroxymethylene- or alkoxymethylene-cycloalkanones lead to interesting cyclic products. The product, e.g., from 2-hydroxymethylenecyclohexanone and cyanoacetamide (in the presence of piperidine or diethylamine),²²⁴ eliminates water between the amide group and the carbonyl group of the cyclohexanone. The hydroxyl of the hydroxymethylene group is also eliminated as water, yielding XI ($\text{R} = \text{H}, \text{CH}_3$).



The dimerization of piperitone²²⁵ (XII) appears to be a special case of Michael condensation. The methyl group of one molecule provides the hydrogen for the saturation of the second; the first molecule behaves, therefore, as a vinylog of a methyl ketone and does not utilize the existing hydrogen in the *ortho* position, perhaps due to steric inhibition by the isopropyl group. Two stereoisomers are formed. The structure of the dimeride of piperitone, which is stabilized by hydrogen bond formation

²¹⁹ Kandiah, *J. Chem. Soc.*, **1931**, 952.

²²⁰ Kon and Thakur, *J. Chem. Soc.*, **1930**, 2217.

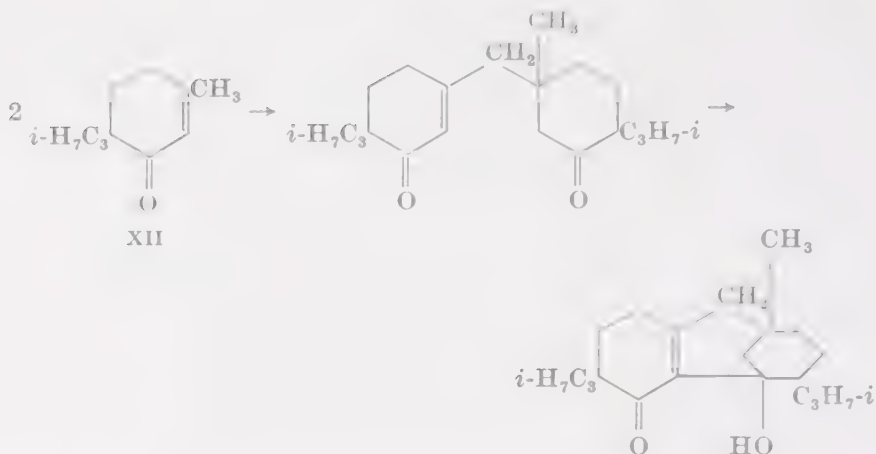
²²¹ Norris and Thorpe, *J. Chem. Soc.*, **119**, 1199 (1921).

²²² Thakur, *J. Chem. Soc.*, **1932**, 2147.

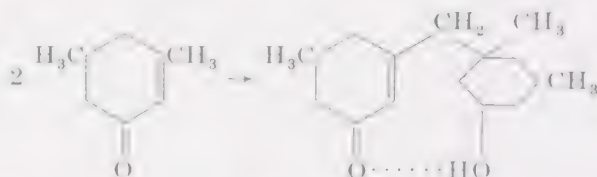
²²³ Thakur, *J. Chem. Soc.*, **1932**, 2157.

²²⁴ Sen-Gupta, *J. Chem. Soc.*, **107**, 1347 (1915).

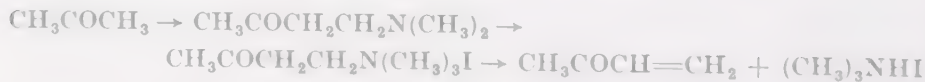
²²⁵ Taylor, *Chemistry & Industry*, **1954**, 252. Cf. Cole, *ibid.*, **1954**, 661.



between the carbonyl and the hydroxyl groups,²²⁶ has been indicated by analogy with evidence obtained by degradation of the dimeride of 3,5-dimethyl-2-cyclohexen-1-one.²²⁷



Robinson's Modification of the Michael Condensation (Table VIII). The use of a masked form of the α,β -ethylenic carbonyl compound, which produces the latter *in situ*, is of practical importance with sensitive ketones and in condensations requiring stringent experimental conditions. Although saturated β -chloroketones had had some use as precursors of the corresponding α,β -ethylenic ketones,²²⁸ Robinson and his co-workers^{98,229-231} introduced the use of β -dialkylaminoketones or their quaternary salts; these decompose gradually into a dialkylamine or trialkylammonium salt and the desired α,β -ethylenic ketone. These starting materials are readily accessible by appropriate Mannich reactions²³² of saturated ketones and, if necessary, subsequent quaternization as shown in the accompanying reaction sequence.



²²⁶ Briggs and Colebrook, *Chemistry & Industry*, **1955**, 200.

²²⁷ Ayer and Taylor, *J. Chem. Soc.*, **1955**, 2227.

²²⁸ Allen and Bell, *Can. J. Research*, **11**, 40 (1934) [*C.A.*, **29**, 150 (1935)].

²²⁹ du Feu, McQuillin, and Robinson, *J. Chem. Soc.*, **1937**, 53.

²³⁰ McQuillin and Robinson, *J. Chem. Soc.*, **1938**, 1097.

²³¹ McQuillin and Robinson, *J. Chem. Soc.*, **1941**, 586.

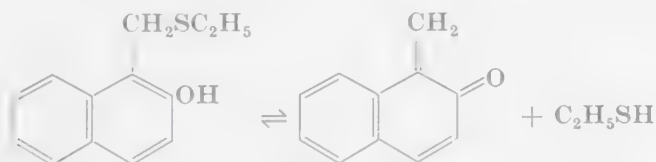
²³² Blicke, in Adams, *Organic Reactions*, Vol. 1, Chapter 10, John Wiley & Sons, 1942.

Although these reactions are included here (Table VIII) among Michael condensations, it has not been certain that they proceed by way of the α,β -ethylene ketone as an intermediate.²³³ A recent study of these reactions has led to the conclusion that the olefinic intermediate, as outlined by Robinson, occurs whenever there is a hydrogen atom on the carbon atom beta to the nitrogen.*

The scope of Robinson's modification of the Michael reaction has been widened by the observation²⁵¹ that 1-dialkylamino-2-nitroalkanes (the Mannich bases of nitroalkanes) can replace the corresponding nitroolefins in Michael condensations.



Another variant is the use of the alkylthio instead of the dialkylamino group. Thus, 1-ethylthiomethyl-2-naphthol reacts as the 1-methylene derivative of the keto form of 2-naphthol.¹⁵⁵



²³³ Brewster and Eliel, in Adams, *Organic Reactions*, Vol. 7, Chapter 3, John Wiley & Sons, 1953.

* Note, however, that Bradford and co-workers²³⁴ have observed differences of reaction in cyanoethylation with β -diethylaminoethyl cyanide methiodide as compared with cyanoethylation with acrylonitrile, and have assumed that the positive ion $NCCH_2CH_2^+$ is the intermediate. This explanation suggests the relation of the Michael condensation to reactions of typical Michael donors with gramine (β -diethylaminoethylindole) and its derivatives.

²³⁴ Bradford, Meek, Turnbull, and Wilson, *Chemistry & Industry*, **1951**, 839.

²³⁵ Eliel and Murphy, *J. Am. Chem. Soc.*, **75**, 3589 (1953).

²³⁶ Dornow and Theis, *Ann.*, **581**, 219 (1953).

²³⁷ Holland and Naylor, *J. Chem. Soc.*, **1953**, 280.

²³⁸ Gray, *J. Am. Chem. Soc.*, **75**, 1252 (1953).

²³⁹ Kissman and Witkop, *J. Am. Chem. Soc.*, **75**, 1967 (1953).

²⁴⁰ Atkinson, Poppelsdorf, and Williams, *J. Chem. Soc.*, **1953**, 580.

²⁴¹ Jones and Kornfeld, U.S. pat. 2,621,187 [C.A., **47**, 10557 (1953)].

²⁴² Kutscher and Klamerth, *Chem. Ber.*, **86**, 352 (1953).

²⁴³ Brewster and Eliel, in Adams, *Organic Reactions*, Vol. 7, p. 99, John Wiley & Sons, 1953.

²⁴⁴ Thesing, *Chem. Ber.*, **87**, 692 (1954).

²⁴⁵ Atkinson, *J. Chem. Soc.*, **1954**, 1329.

^{245a} Hellmann, Hallmann, and Lingens, *Chem. Ber.*, **86**, 1346 (1953).

²⁴⁶ Hardegger and Corrodi, *Helv. Chim. Acta*, **38**, 468 (1955).

²⁴⁷ Albertson, Archer, and Suter, *J. Am. Chem. Soc.*, **66**, 500 (1944).

²⁴⁸ Snyder and Smith, *J. Am. Chem. Soc.*, **66**, 350 (1944).

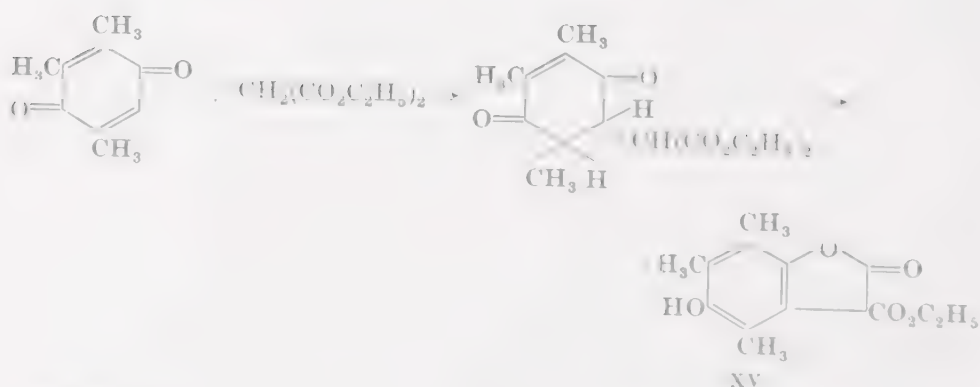
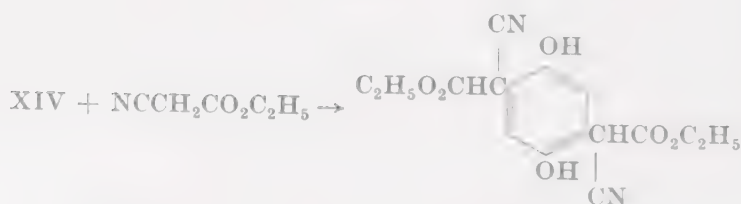
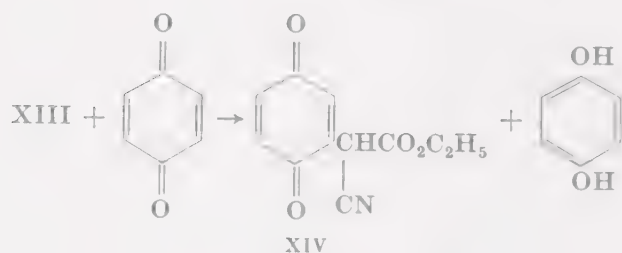
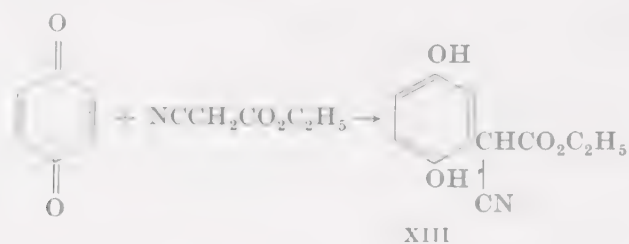
²⁴⁹ Lytle and Weisblat, *J. Am. Chem. Soc.*, **69**, 2118 (1947).

²⁵⁰ Hegedus, *Helv. Chim. Acta*, **29**, 1499 (1946).

²⁵¹ Shoemaker and Keown, *J. Am. Chem. Soc.*, **76**, 6374 (1954).

***p*-Quinones and Derivatives (Table IX).** As in many other reactions, e.g., the Diels-Alder synthesis, *p*-quinones behave in the Michael condensation as α,β -ethylenic ketones. However, although the enols formed in the Michael condensation of most α,β -ethylenic ketones ketonize spontaneously, the enols formed from quinones are hydroquinones and are stable.

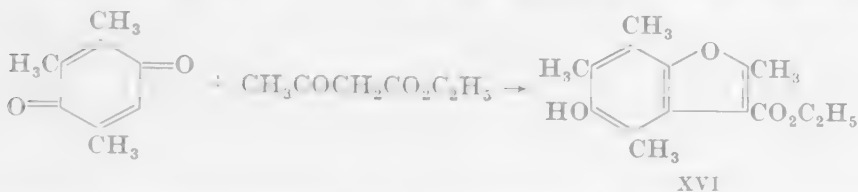
Certain of the hydroquinone products are dehydrogenated *in situ* by an excess of the original quinone, so that the newly formed quinone can undergo a second Michael condensation.²⁵²



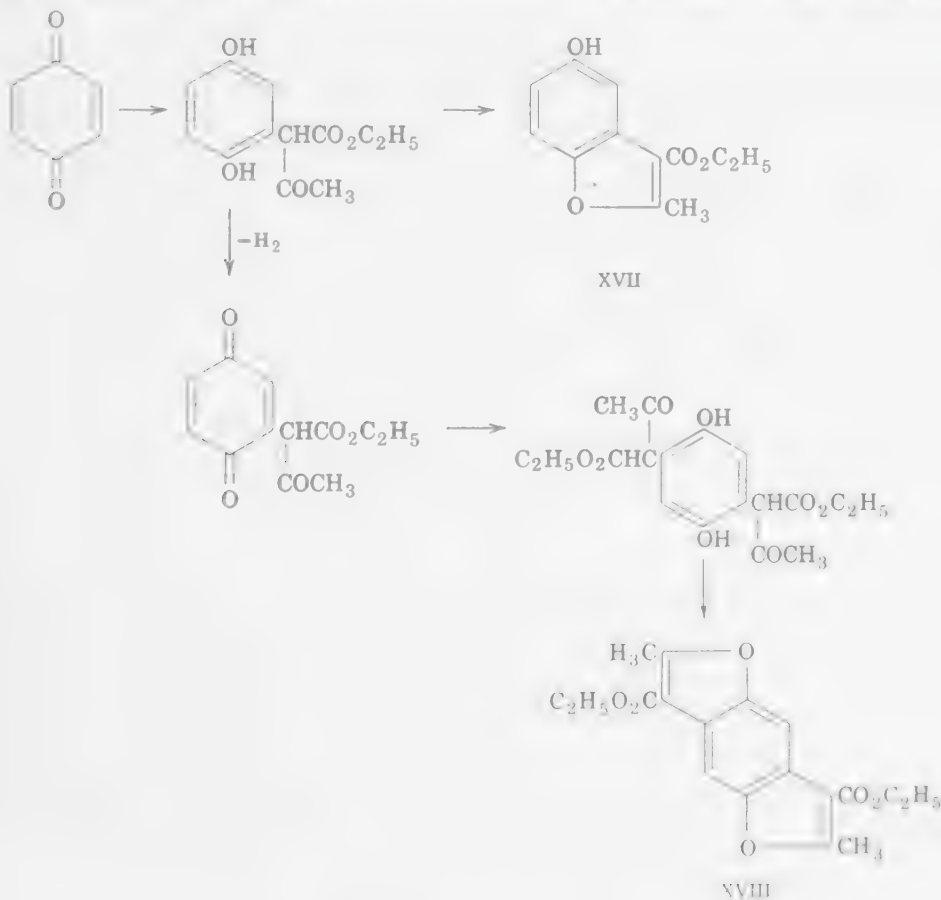
²⁵² Wood, Colburn, Jr., Cox, and Garland, *J. Am. Chem. Soc.*, **66**, 1540 (1944)

Other hydroquinones undergo cyclization involving the hydroxyl group of the hydroquinone and leading to condensed heterocyclic ring systems. As example is the formation of the lactone XV shown on p. 224.²⁵³

In other cases not only isocoumarones are formed, but also coumarin derivatives such as XVI.²⁵⁴ When zinc chloride is used to catalyze the



reaction of *p*-benzoquinone and ethyl acetoacetate, either a mono (XVII) or bis derivative (XVIII) can be formed.²⁵⁵⁻²⁵⁷ Cyclization also takes place



²⁵³ Smith and Prichard, *J. Org. Chem.*, **4**, 342 (1939).

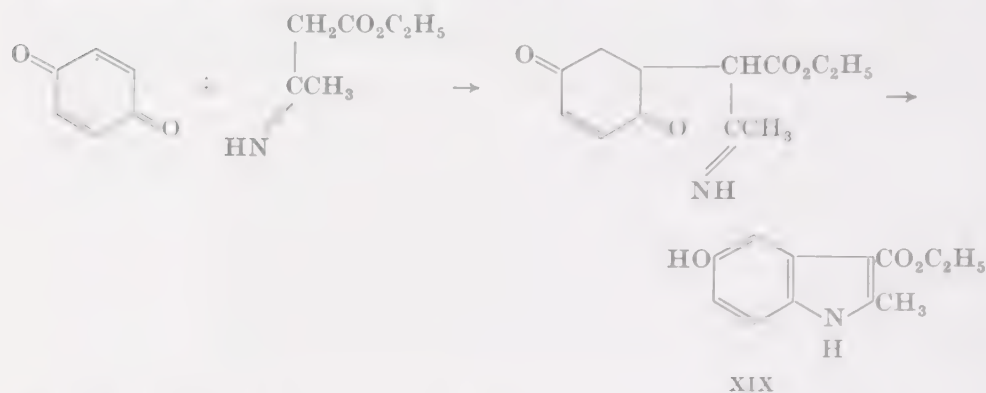
²⁵⁴ Smith and Boyack, *J. Am. Chem. Soc.*, **70**, 2690 (1948).

²⁵⁵ Pechmann, *Ber.*, **21**, 3005 (1888).

²⁵⁶ Ikuta, *J. prakt. Chem.*, [2], **45**, 78 (1892).

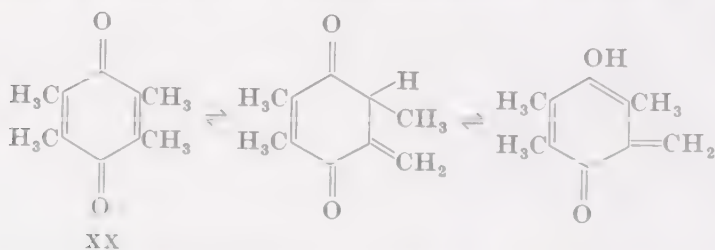
²⁵⁷ Graebe and Levy, *Ann.*, **283**, 245 (1894).

when benzoquinone reacts with the imine of ethyl acetoacetate (ethyl β -aminocrotonate). In acetone or anhydrous ethanol as solvent, 2-methyl-3-carbethoxy-5-hydroxyindole (XIX) is formed.²⁵⁸ In the same way,



N-phenyl-2-methyl-3-carbethoxy-5-hydroxyindole was obtained with ethyl β -anilinoacronate, and the corresponding N-carbethoxymethyl compound from ethyl β -(carbethoxymethylamino)crotonate.

Ordinarily only an unsubstituted carbon atom of the quinone ring is attacked by a donor anion, possibly for steric reasons. Thus, trisubstituted quinones undergo only mono condensation.^{254,259,260} However, it



is possible for a tetrasubstituted quinone to participate in the Michael condensation.²⁶¹⁻²⁶³ A substance like duroquinone (XX) presumably reacts in a tautomeric form (considered to be the intermediate in the "dimerization" of this quinone),²⁶⁴ which is evidently much freer of steric hindrance than the normal form.

In one instance, a methylene quinone (1-methylene-1,2-naphthoquinone, XXI) has been shown to undergo the Michael reaction with diethyl

²⁵⁸ Neri, *Ann. Chim. (Milan)*, **11**, 37 (1929); *ibid.*, **24**, 110 (1930).

²⁵⁹ Smith and Kaiser, *J. Am. Chem. Soc.*, **62**, 133 (1940).

²⁶⁰ Smith and King, *J. Am. Chem. Soc.*, **65**, 441 (1943).

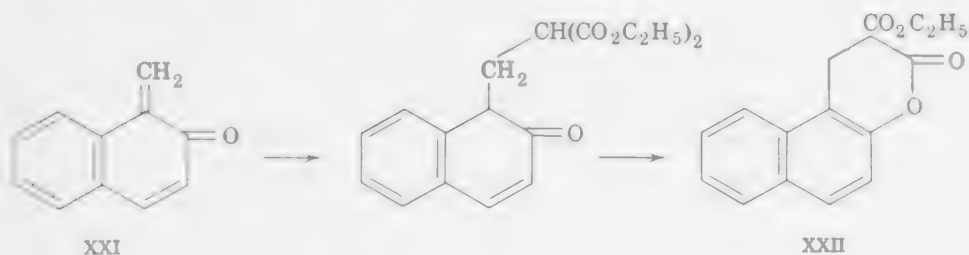
²⁶¹ Smith and Dobrovolsky, *J. Am. Chem. Soc.*, **48**, 1693 (1926).

²⁶² Smith and Kaiser, *J. Am. Chem. Soc.*, **62**, 138 (1940).

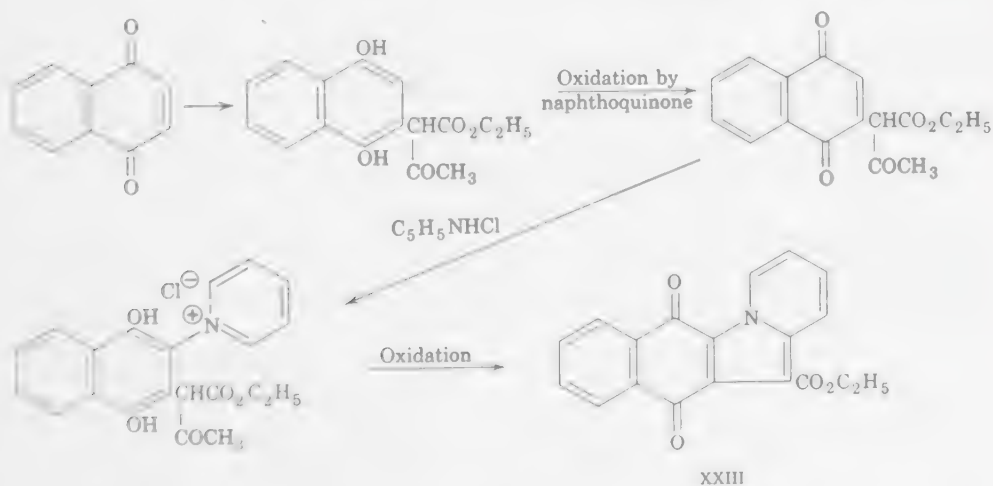
²⁶³ Smith and Tenenbaum, *J. Am. Chem. Soc.*, **59**, 667 (1937).

²⁶⁴ Smith, Tess, and Ulliot, *J. Am. Chem. Soc.*, **66**, 1320 (1944).

malonate, though in small yield. In this case, too, cyclization occurred and ethyl 5,6-benzo-3,4-dihydrocoumarin-3-carboxylate (XXII) was formed.²⁶⁵



A complicated modification of the Michael reaction of *p*-quinones has been observed to result from condensation of 1,4-naphthoquinone (cf. ref. 261) with ethyl acetoacetate in the presence of pyridine and pyridinium hydrochloride;²⁶⁶ cf. ref. 267. The final product had lost the acetyl group of the acetoacetate molecule; the same product (1-carbethoxy-2,3-phthaloylpyrrocoline, XXIII) was therefore obtained when ethyl benzoyl-acetate was employed. The reaction has been formulated as shown.



The complexity of this sequence explains the low yield (14%) as well as the fact that also 2-bromo- and 2,3-dichloro-naphthoquinone and 1,4-naphthoquinone 2 sulfonate give the same product, with loss of the polar

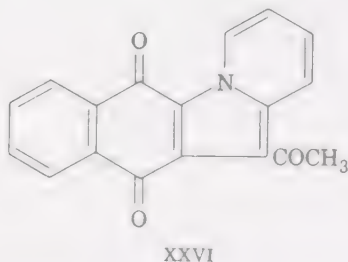
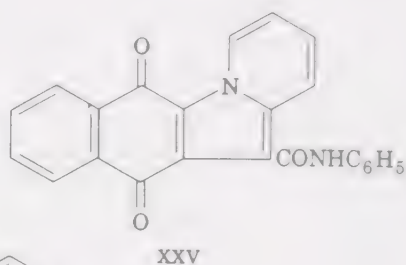
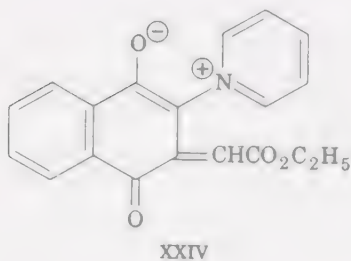
²⁶⁵ Smith and Horner, Jr., *J. Am. Chem. Soc.*, **60**, 676 (1938).

²⁶⁶ Pratt, Luckenbaugh, and Erickson, *J. Org. Chem.*, **19**, 176 (1954).

²⁶⁷ Post and Bunn, *J. Am. Chem. Soc.*, **73**, 444 (1951). Isoquinoline shows a reactivity comparable with that of pyridine. Quinoline, however, is relatively unreactive and the products described in ref. 266 as derived from quinoline have been shown to have been formed from isoquinoline present in the quinoline used. Pratt, Rice, and Luckenbaugh, *J. Am. Chem. Soc.*, **79**, 1212 (1957).

substituents.²⁶⁸ According to Suryanarayana and Tilak,²⁶⁹ 2,3-dichloro-naphthoquinone also yields the same compound (XXIII) when condensed with diethyl malonate or ethyl benzoylacetate. The Indian authors assigned to it, originally, the formula XXIV, but withdrew it later in favor of XXIII.²⁷⁰⁻²⁷³

They further observed, in the condensation of 2,3-dichloro-1,4-naphthoquinone with acetoacetanilide in pyridine, that the ultimate partial degradation of the side chain involved *either* the acetyl *or* the anilide group, thus leading both to XXV and XXVI. Compound



XXVI is also obtained when acetoaceto-*o*-chloroanilide, *o*-toluide, or 2-(acetoacetanilido)-6-ethoxybenzothiazole is employed instead of the unsubstituted anilide.

An analogous reaction was observed when ethyl acetoacetate in pyridine solution was condensed with chloranil or 2,6-dichloroquinone, leading to a mixture of XXVIIA and XXVII B. The structure of XXVIIA was proved by its synthesis from tetraethyl 2,5-dichloroquinone-3,6-dimalonate and ethyl acetoacetate in pyridine solution.

²⁶⁸ Michel, *Ber.*, **33**, 2402 (1900).

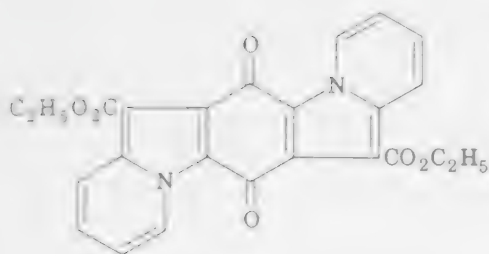
²⁶⁹ Suryanarayana and Tilak, *Proc. Indian Acad. Sci.*, **39A**, 185 (1954) [*C.A.*, **49**, 1741] (1955).

²⁷⁰ Suryanarayana and Tilak, *Proc. Indian Acad. Sci.*, **38A**, 534 (1953) [*C.A.*, **49**, 2296] (1955).

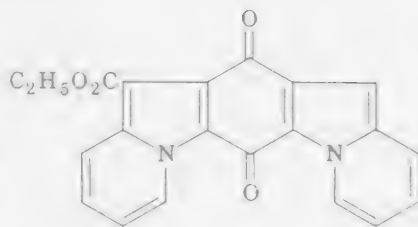
²⁷¹ Suryanarayana and Tilak, *Chem. Sci. Ind.*, **22**, 171 (1953) [*C.A.*, **48**, 14212] (1954).

²⁷² Acharya, Tilak, and Venkiteswaran, *J. Sci. Ind. Research India*, **14B**, 250 (1955) [*C.A.*, **50**, 15531] (1956).

²⁷³ Acharya, Suryanarayana, and Tilak, *J. Sci. Ind. Research India*, **14B**, 394 (1955) [*C.A.*, **50**, 15771] (1956).

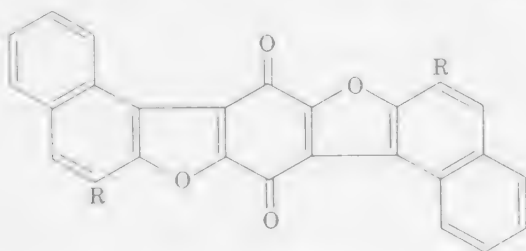


XXVIIA



XXVIIB

Chloranil enters also into Michael reactions with β -naphthol or 2-hydroxy-3-naphthanilide. These donors react in their tautomeric keto forms as in several other instances (see p. 211), and cause the loss of the halogen atoms, leading to compounds of the following type.



(R = H, CONHC₆H₅)

Acrylonitrile, Other α,β -Unsaturated Nitriles, and Their Amides (Tables X, XI, and XIA). Acrylonitrile has been used as an acceptor in Michael synthesis more widely than any other derivative of α,β -ethylenic acids. The reaction with acrylonitrile has not only been used for preparative purposes, but it has become a tool for testing organic molecules for enolizable hydrogen atoms. The literature is summarized in Table X, which also brings up to date an earlier review of the cyanoethylation reaction.²⁷⁴

Some interesting generalizations emerge from Table X. In aliphatic methyl ketones, a methine group adjacent to the carbonyl is more reactive than a methylene group, and a methylene group is more reactive than a methyl group.²⁷⁵⁻²⁷⁷ In cyclohexanone and 2-substituted cyclohexanones, hydrogen in the 2 position reacts first with acrylonitrile,^{274,275,278,279} when no more labile hydrogen remains at the 2 position, the 6 position is

²⁷⁴ Bruson, in Adams, *Organic Reactions*, Vol. 5, p. 79, John Wiley & Sons, 1949. See also U.S. pat. 2,386,736 [C.A., **40**, 7234 (1946)].

²⁷⁵ Barkley and Levine, *J. Am. Chem. Soc.*, **72**, 3699 (1950).

²⁷⁶ Campbell, Carter, and Slater, *J. Chem. Soc.*, **1948**, 1741.

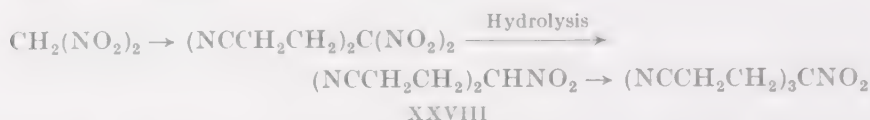
²⁷⁷ Zellars and Levine, *J. Org. Chem.*, **13**, 911 (1948).

²⁷⁸ Bruson and Niederhauser, U.S. pat. 2,437,906 [C.A., **42**, 4196 (1948)].

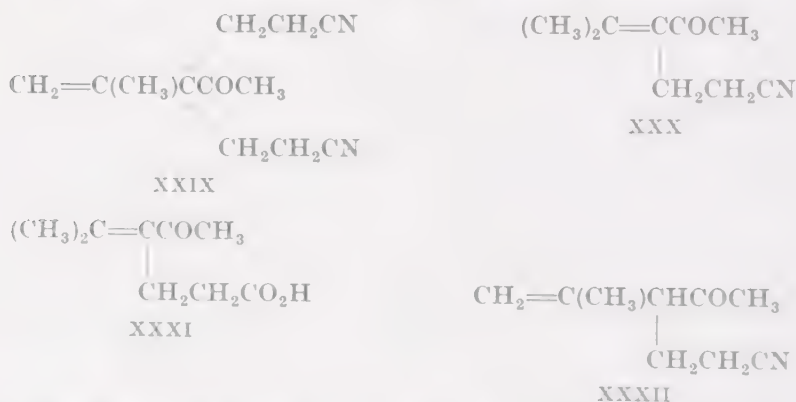
²⁷⁹ Bruson and Riener, *J. Am. Chem. Soc.*, **70**, 214 (1948).

attacked by the nitrile.^{279,279} In aryl methyl ketones, all three hydrogen atoms of the methyl group react successively with acrylonitrile.²⁷⁷

Nitromethane and nitroethane are reported to give varying yields in the reaction with acrylonitrile.^{117,280-282} Dinitromethane, on the other hand, readily gives bis(cyanoethyl)dinitromethane, which loses one nitro group, and the scission product reacts with a third molecule of acrylonitrile to yield tris(cyanoethyl)nitromethane.⁸⁰⁹



In some α,β -ethylenic carbonyl and carboxyl compounds, the inherent possibility of tautomerization to the β,γ -unsaturated forms is enhanced by the reaction with acrylonitrile. From mesityl oxide, for example, a mono and a bis adduct are obtained;^{283,284} cf. ref. 764. For the latter, the formula XXIX has been established by degradation. For the former, Bruson and Riener have proposed the α,β -unsaturated structure XXX because of the formation of XXXI by hydrolysis. The evidence does



not exclude the possibility, however, that during hydrolysis the double bond shifts into the α,β position and that the correct structure is the one shown in XXXII. In any event, XXXII undoubtedly represents the structure of the primary product of the interaction between acrylonitrile and mesityl oxide.

Revising a previous statement²⁸³ on the reaction of isophorone with acrylonitrile, Bruson and Riener have obtained mono-, bis-, and

²⁸⁰ Thurston, Can. pat. 443,713 [*C.A.*, **42**, 205 (1948)].

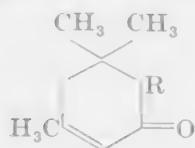
²⁸¹ Wulff, Hopff, and Wiest, Ger. pat. 728,531 [*C.A.*, **38**, 376 (1944)].

²⁸² Bruson and Riener, *J. Am. Chem. Soc.*, **65**, 23 (1943).

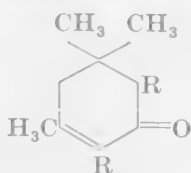
²⁸³ Bruson and Riener, *J. Am. Chem. Soc.*, **64**, 2850 (1942).

²⁸⁴ Bruson and Riener, *J. Am. Chem. Soc.*, **66**, 56 (1944).

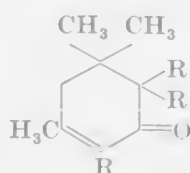
tricyanoethyl derivatives (XXXIII to XXXV) of isophorone, to which they assigned the following structures ($R = CH_2CH_2CN$).²⁸⁵



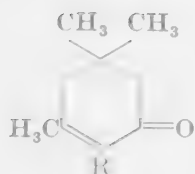
XXXIII



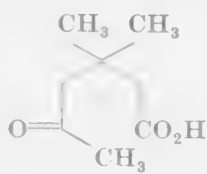
XXIV



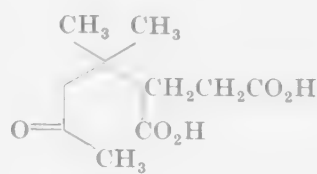
XXXV



XXXVI

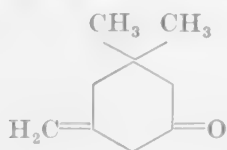


XXXVII

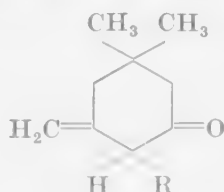


XXXVIII

However, it has been shown²⁸⁶ that the mono derivative is XXXVI, as it could be ozonized to yield 3,3-dimethyl-5-ketohexanoic acid (XXXVII) (after hydrolysis of the nitrile group), whereas XXXIII should have given XXXVIII. As in the case of mesityl oxide (p. 230), the tautomeric

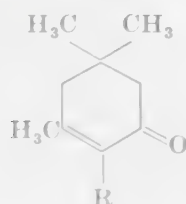
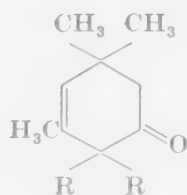
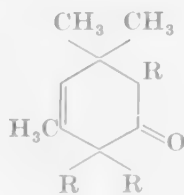


XXXIX



XL

form (XXXIX) of isophorone undergoes reaction; the primary product XL then isomerizes to an α,β -unsaturated ketone. The infrared spectra of the bis and tris products reported by Bruson and Riener²⁸⁵ suggest the following structures for the mono-, di-, and tri-cyanoethylated products, respectively.

 $\lambda = 6.05$  $\lambda = 5.90$  $\lambda = 5.90$

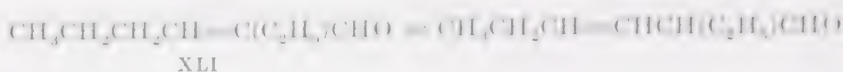
The alkylation of isophorone takes place in an analogous manner.²⁸⁷

²⁸⁵ Bruson and Riener, *J. Am. Chem. Soc.*, **75**, 3585 (1953).

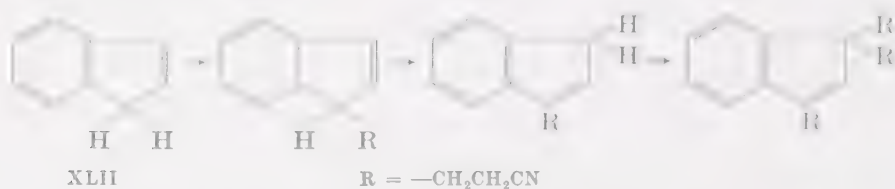
²⁸⁶ Juha, *Compt. rend.*, **237**, 913 (1953).

²⁸⁷ Coma, *Bull. soc. chim. France*, **1954**, 690.

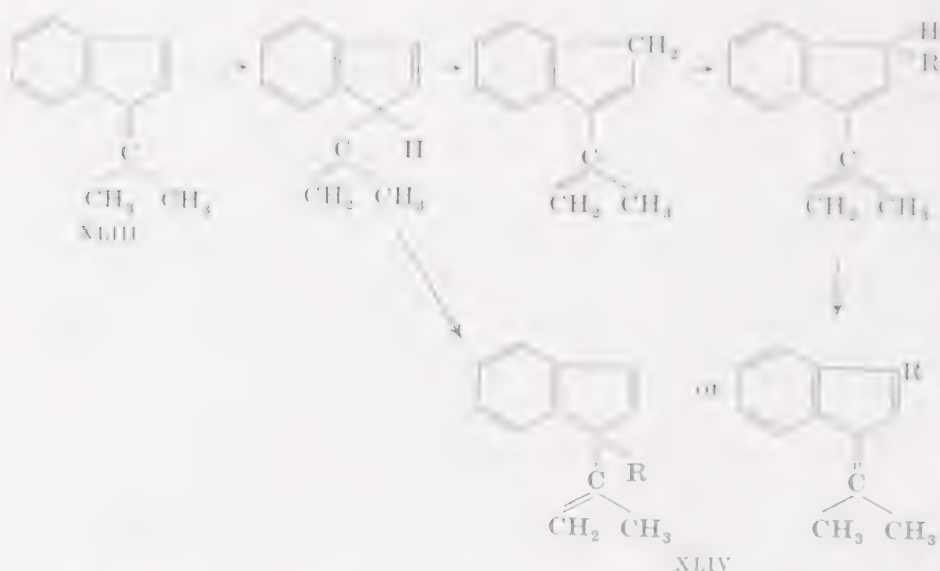
2-Ethyl-2-hexenal (XLI) also reacts in the β/γ -isomeric form with crotononitrile and β,β -dimethylacrylonitrile.



An interesting point emerges from the behavior of compounds such as indene (XLII),²⁸⁸ which gives a tris(cyanoethyl) derivative. One has to assume that the primary products rearrange to give a new reactive methylene group. In a similar fashion, cyclopentadiene gives a hexacyanoethyl derivative.

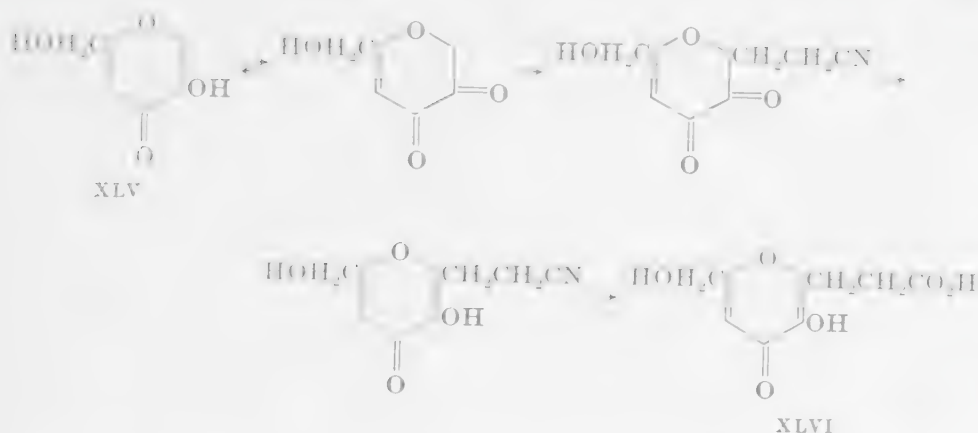


In the reaction of dimethylbenzofulvene (XLIII), which gives a mono derivative XLIV, it has been supposed that an isomerization precedes the reaction.



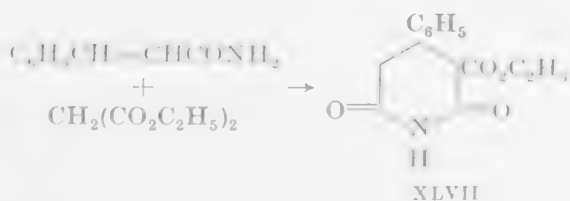
Kojic acid (XLV) provides an instance in which an *enolic* hydroxyl group reacts in the tautomeric keto form.²⁸⁹ after hydrolysis the product is a 6-propionic acid derivative (XLVI) of kojic acid:

²⁸⁸ Bruson, *J. Am. Chem. Soc.*, **64**, 2457 (1942).



Considerably less work has been done on the Michael condensation with other unsaturated nitriles. The available data, collected in Table XI, deal mainly with cinnamonnitrile,^{27,289,290} and allyl cyanide,^{27,77,117,291} isomerized to crotononitrile by the alkaline reagents that catalyze the Michael condensation. Table XI also includes some data on 1-cyanobutadiene^{91,292,293}. In contradistinction to $\alpha,\beta,\gamma,\delta$ -diethylenic ketones (see p. 217), the Michael condensation of 1-cyanobutadiene with nitroalkanes takes place in the 1,6 positions, yielding β,γ -unsaturated nitriles.²⁹³

α,β -Unsaturated amides could be expected to react in the same manner as the nitriles. Acrylamide adds, in the presence of benzyltrimethylammonium hydroxide, one molecule of 2-nitropropane,²⁹⁴ and cinnamamide condenses with diethyl sodiomalonate to give the normal 1:1 adduct which cyclizes to yield ethyl 2,6-diketo-4-phenylpiperidine-3-carboxylate (XLVII).^{294a} However, in the reactions studied (Table XI4) acrylamide appears to offer no particular advantage for synthesis.²⁹⁵



²⁸⁹ Campbell and Fairfull, *J. Chem. Soc.*, **1949**, 1239.

²⁹⁰ Koelsch, *J. Am. Chem. Soc.*, **65**, 2459 (1943).

²⁹¹ Tucker, *J. Chem. Soc.*, **1949**, 2182.

²⁹² Bruson, U.S. pat. 2,484,683 [*C.A.*, **44**, 5904 (1950)].

²⁹³ Charlsh, Davies, and Rose, *J. Chem. Soc.*, **1948**, 227.

²⁹⁴ Bruson, U.S. pat. 2,370,142 [*C.A.*, **39**, 3544 (1945)].

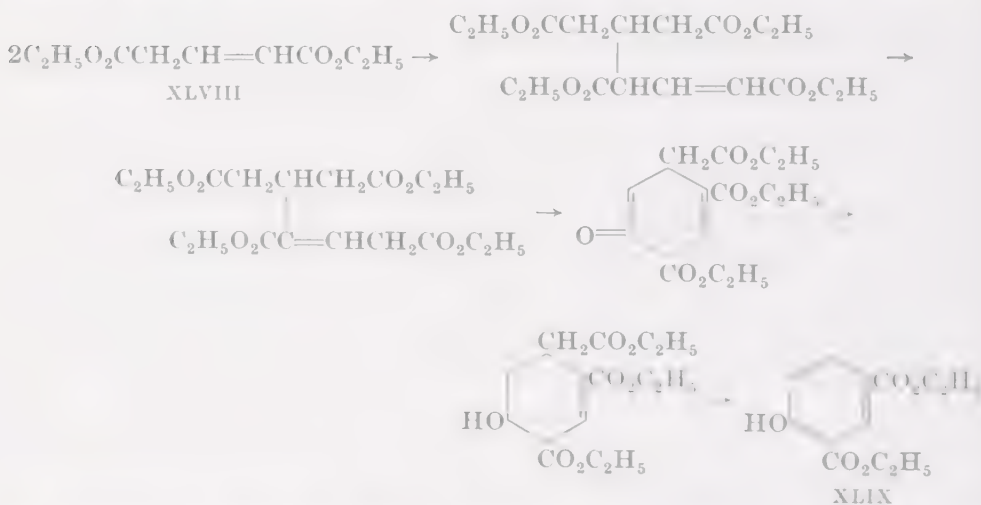
^{294a} Herrmann and Vorlaender, *Chem. Zentr.*, **1899**, **I**, 730.

²⁹⁵ Elal and Ginsburg, *J. Chem. Soc.*, **1953**, 4137.

α,β -Ethylenic Aliphatic Esters (Tables XII, XIII, XIV). The Michael condensations that have been carried out with α,β -ethylenic aliphatic esters (Table XII) show that activation by a carbalkoxy group is less strong than that effected by a nitro group.

A number of saturated α - and β -hydroxy esters react with ethyl cyanoacetate as if they were first dehydrated to α,β -ethylenic esters, which then undergo the Michael condensation;²⁹⁶ the same applies to certain cyanohydrins.²⁹⁷ In view of the uncertainty of the mechanism, these reactions have not been listed in Table XII. Likewise, the dimerization of methyl acrylate and ethyl acrylate^{2,298-300} can be considered formally as involving a Michael reaction, but it probably proceeds by a different mechanism.

The self-condensation of diethyl glutaconate (XLVIII) under the influence of sodium ethoxide is, by contrast, a typical Michael condensation. It can be formulated as involving an intermediary shift of the double bond. Part of the product aromatizes, by elimination of ethyl acetate, to give diethyl 4-hydroxyisophthalate (XLIX).³⁰¹ One molecule



of glutaconate, therefore, acts as a donor, and a second one as acceptor. (Under the influence of metallic sodium, a Claisen condensation takes place.³⁰² The same interpretation applies to the self-condensation of trimethyl propylene-2,3,3-tricarboxylate, which involves two successive

²⁹⁶ Ingold, *J. Chem. Soc.*, **119**, 329 (1921).

²⁹⁷ See, e.g., Higson and Thorpe, *J. Chem. Soc.*, **89**, 1455 (1906).

²⁹⁸ Pechmann, *Ber.*, **33**, 3323 (1900).

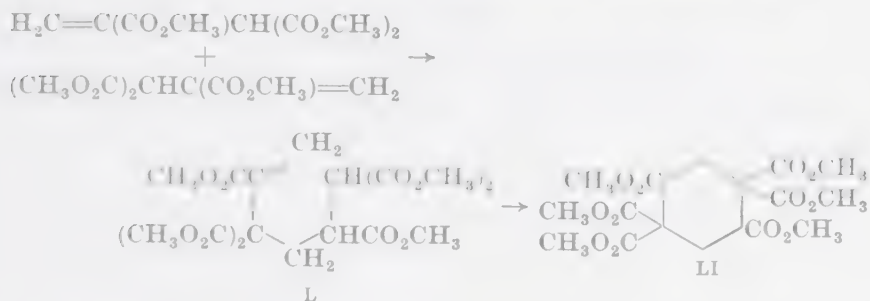
²⁹⁹ Pechmann and Roehm, *Ber.*, **34**, 427 (1901).

Bergmann, *Chem. Revs.*, **29**, 529 (1941).

³⁰⁰ Pechmann, Bauer, and Obermiller, *Ber.*, **37**, 2113 (1904).

³⁰¹ Blaise, *Compt. rend.*, **136**, 692 (1903); *Bull. soc. chim. France*, [3], **29**, 1028 (1903).

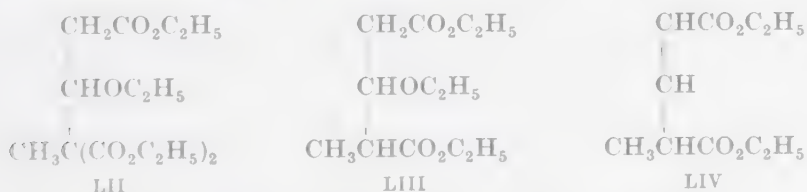
Michael condensations. The first yields the open-chain ester L, whereas the second is intramolecular and yields the cyclic product LI.³⁰³



The addition of ethyl 5-methylcyclopentanone-2-carboxylate to ethyl crotonate involves the α -hydrogen atom in the 2 position, and not in the 5 position as erroneously stated in the abstract literature.^{304,305}

The Michael reaction is not involved in the condensation of ethyl acetoacetate and diethyl acetone-1,3-dicarboxylate to diethyl 3,5-dihydroxytoluene-2,4-dicarboxylate.³⁰⁶

Table XIII is devoted to reactions of β -hydroxy-, β -ethoxy-, and β -amino- α,β -ethylenic esters. These reactions are generally accompanied by the elimination of the β substituent (as water, alcohol, or ammonia, respectively). For example, when ethyl β -ethoxyacrylate is condensed with diethyl methylmalonate under the catalytic influence of benzyltrimethylammonium ethoxide, the expected triester LII not only undergoes ethanolysis to diethyl carbonate and the diester LIII but the diester decomposes further to give ethanol and the unsaturated ester LIV.³⁰⁷



The behavior of diethyl 2-ethoxyethylene-1,1-dicarboxylate LV is very similar.³⁰⁸⁻³¹⁰ With nitromethane and secondary bases the ester LV

³⁰³ Baker, *J. Chem. Soc.*, **1935**, 188.

³⁰⁴ Sen-Gupta, Chakraborti, and Bhattacharayya, *J. Indian Chem. Soc.*, **24**, 249 (1947) [*C.A.*, **43**, 2584 (1949)].

³⁰⁵ Private communication from Dr. B. K. Bhattacharayya.

³⁰⁶ Koller and Krakauer, *Monatsh.*, **53-54**, 931 (1929).

³⁰⁷ Croxall and Fegley, *J. Am. Chem. Soc.*, **72**, 970 (1950).

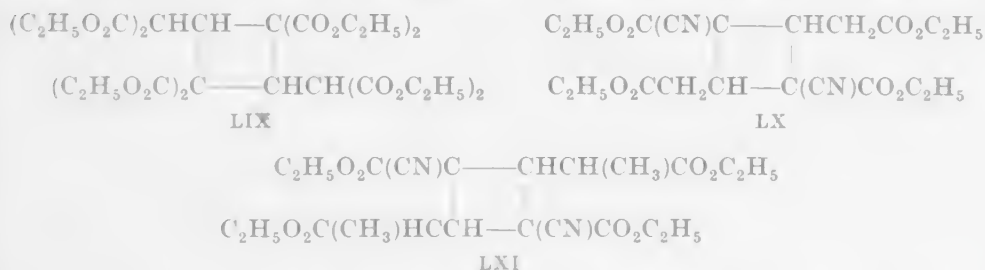
³⁰⁸ Menon, *J. Chem. Soc.*, **1935**, 1061.

³⁰⁹ Menon, *J. Chem. Soc.*, **1936**, 1775.

³¹⁰ Simonsen, *J. Chem. Soc.*, **93**, 1022 (1908).

mesaconate; this is the only example of the use of this *trans* compound as an acceptor in the Michael condensation.³¹⁷

In the Michael condensation of esters of polycarboxylic acids, two tendencies are apparent. First, the highly substituted reaction products tend to dissociate into simpler substances by elimination of some smaller molecules, such as ethanol or diethyl malonate, with formation of a double bond.^{315,318-321} Second, those adducts containing both an enolizable hydrogen atom and a suitable acceptor structure undergo an intramolecular Michael condensation with the formation of a six-membered ring. Tetraethyl propylene-1,1,3,3-tetracarboxylate is reported to lead, under the influence of piperidine or sodium ethoxide, to the cyclobutane derivative LIX,³²¹⁻³²³ and piperidine converts diethyl



3-cyanopropylene-1,3-dicarboxylate and diethyl 4-cyanobutylene-2,4-dicarboxylate into the cyclobutanes LX and LXI, respectively.^{322,323} However, reaction of diethyl acetylenedicarboxylate with tetraethyl ethane-1,1,2,2-tetracarboxylate has been recently shown^{324,325} to give not a cyclobutane derivative but hexaethyl butene-1,1,2,2,3,4-hexacarboxylate.

Table XIV summarizes our knowledge of the behavior of aliphatic dienic esters and one trienic ester in the Michael condensation. With the dienic esters, 1,6 addition predominates over 1,4 addition; with the trienic ester, 1,8 addition predominates. This, however, applies only to cases in which the polar groups are unsymmetrically distributed about the double bond: dialkyl muconates, $\text{RO}_2\text{CCH}=\text{CHCH}=\text{CHCO}_2\text{R}$, undergo 1,4 addition exclusively, giving $\text{RO}_2\text{CCH}=\text{CHCH}(\text{R}')\text{CH}_2\text{CO}_2\text{R}$.³²⁶

³¹⁷ Hope, *J. Chem. Soc.*, **101**, 892 (1912).

³¹⁸ Cornforth and Robinson, *J. Chem. Soc.*, **1949**, 1855.

³¹⁹ Cox and McElvain, *J. Am. Chem. Soc.*, **56**, 2459 (1934).

³²⁰ Cox, Kroecker, and McElvain, *J. Am. Chem. Soc.*, **56**, 1173 (1934).

³²¹ Guthzeit, *Ber.*, **34**, 675 (1901).

³²² Ingold, Perren, and Thorpe, *J. Chem. Soc.*, **121**, 1765 (1922), especially p. 1788.

³²³ Verkade, *Verslag. Akad. Wetenschappen Amsterdam*, **27**, 1130 (1919) [*C.A.*, **13**, 3149 (1919)].

³²⁴ Overberger and Kabasakalian, *J. Am. Chem. Soc.*, **75**, 6058 (1953).

³²⁵ Reid, *Chemistry & Industry*, **1953**, 846.

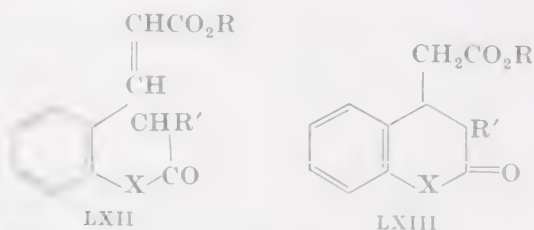
³²⁶ Farmer, *J. Chem. Soc.*, **121**, 2015 (1922).

Alicyclic and Aromatic α,β -Ethylenic Esters (Tables XV and XVI). In the alicyclic series, a small number of Michael condensations have been carried out (Table XV). These proceed normally, and the only point of interest is that the reactions of ethyl cyclopentenecarboxylate with ethyl acetoacetate and diethyl malonate, respectively, give exclusively the *trans* form of the reaction products.³² As pointed out on p. 199, relatively little is known of the stereochemistry of the Michael reaction.

In the aromatic series, even fewer reactions have been studied (Table XVI). Acetophenone gives a Michael condensation with methyl and ethyl cinnamate; it is in competition, however, with a Claisen condensation between the reactants under the influence of sodium amide or sodium. Acetone undergoes with alkyl cinnamates the Claisen reaction exclusively.^{327,328}

The three dienic esters that have been studied do not give a consistent picture. In two of them 1,6 and in one 1,4 addition takes place, without any obvious difference either in the structure of the unsaturated ester or in the operating conditions.^{56,194,195,329}

Ortho-substituted aromatic α,β -ethylenic esters provide ideal structures for internal Michael condensation. If one introduces in the ortho position to the unsaturated ester group a substituent that contains an enolizable hydrogen atom at a suitable distance from the ring, a bicyclic system can be formed easily. This possibility has been utilized with substances of the general formula LXII for the synthesis of bicyclic systems such as LXIII, where X = O, S, or N-alkyl. The pertinent data form the second part of Table XVI, in which an analogous case from the alicyclic series is also included.



Unsaturated Keto Esters (Table XVII). Table XVII contains the scanty material pertaining to the Michael condensation of unsaturated keto esters, in which the double bond is activated both by a keto and an ester group.^{8,120,310,330,331} It is interesting to note that in esters of the type $\text{RCOCH}=\text{CHCO}_2\text{R}'$, the keto group gives a more stable carbanion

³²⁷ Hauser, Yost, and Ringler, *J. Org. Chem.*, **14**, 261 (1949).

³²⁸ Egan and Tschorn, *Chem. Ber.*, **74**, 322 (1941) [*Chem. Abstr.*, **1913**, **II**, 2033].

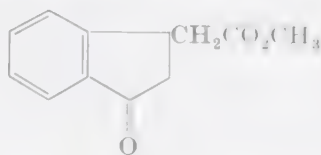
³²⁹ Kohler and Engelbrecht, *J. Am. Chem. Soc.*, **41**, 764 (1919).

³³⁰ Errera, *Ber.*, **33**, 2969, 3469 (1900).

³³¹ Palit, *J. Indian Chem. Soc.*, **14**, 354 (1937) [*C.A.*, **32**, 561 (1938)].

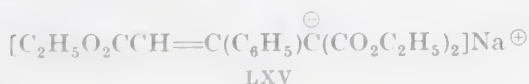
than the ester group, the Michael condensation with a donor R^1H leads to a product of the structure $RCOCH_2CHR''CO_2R'$.

Theoretically, it should be possible to effect internal Michael condensations with *o*-acetyl derivatives of cinnamic acid. It has, indeed, been found that methyl *o*-acetylcinnamate reacts with sodium methoxide, but the expected product LXIV could not be isolated in pure form.³³²

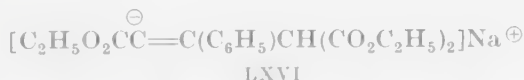


LXIV

Aromatic α,β -Acetylenic Esters (Table XVIII). In the aromatic series, as in the aliphatic, an acetylenic bond in conjunction with an ester group behaves in the Michael condensation like a double bond (Table XVIII). In certain cases, the correct formulation of the anion of the primary product of the condensation appears uncertain. It has been observed, for example, that the condensation of ethyl phenylpropiolate with diethyl malonate, using ethanolic sodium ethoxide and using sodium in benzene, lead to different anions, formulated as LXV and LXVI.^{25,26,333,334} This problem is discussed on p. 186.

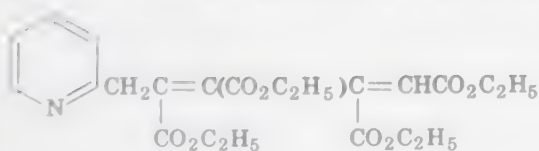


LXV

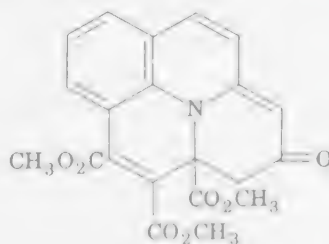


LXVI

It is often thought that the reaction between acetylenic esters and substances like 2-picoline or quinaldine is a specific case of the Michael condensation, although the components react in a 2:1 ratio. Diethyl acetylenedicarboxylate and 2-picoline yield the conjugated diene LXVII;



LXVII



LXVIII

³³² Koelsch and Stephens, Jr., *J. Am. Chem. Soc.*, **72**, 2209 (1950).

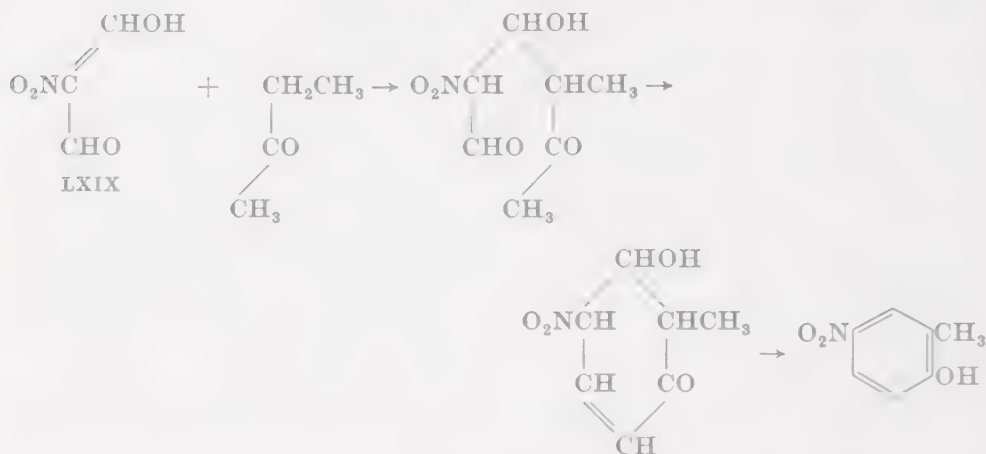
³³³ Farmer, Ghosal, and Kon, *J. Chem. Soc.*, **1936**, 1804.

³³⁴ Michael, *J. Org. Chem.*, **2**, 303 (1938).

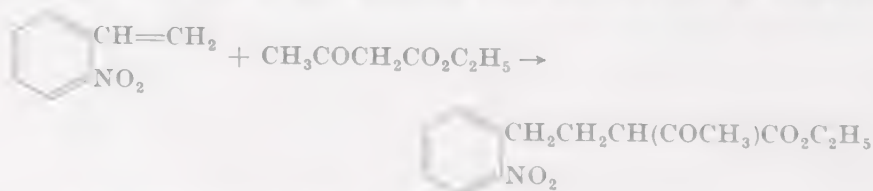
the acetylenic dimethyl ester with 2-quinaldine gives the analogous, but more complex, product LXVIII.³³⁵⁻³³⁷

It is known that similar dimeric forms of acetylenic compounds often occur in the Diels-Alder reaction at least as formal intermediary products.³³⁸

Olefins with Substituents Based on Hetero Atoms (N, S, P; Tables XIX, XX, XXI). A nitro group activates a double bond to which it is attached as it activates adjacent hydrogen atoms. Table XIX summarizes the Michael condensations involving α, β -ethylenic nitro compounds. Data pertaining to hydroxymethylenenitroacetaldehyde (the enolic form of nitromalondialdehyde, LXIX) are included. This



compound reacts with many donor molecules, including even aliphatic ketones, to give derivatives of 4-nitrophenol.^{111,339-343} The reaction with methyl ethyl ketone is illustrative. The activating power of the nitro group is so great that *o*- and *p*-nitrostyrene can also act as acceptors in



³³⁵ Diels, Alder, et al., *Ann.*, **498**, 16 (1932).

³³⁶ Diels and Kech, *Ann.*, **519**, 140 (1935).

³³⁷ Diels and Pistor, *Ann.*, **530**, 87 (1937).

³³⁸ Diels and Alder, *Ann.*, **498**, 16 (1932); *ibid.*, **505**, 103 (1933); *ibid.*, **510**, 87 (1934); Diels and Kock, *ibid.*, **556**, 38 (1944).

³³⁹ Hill and Torrey, Jr., *Am. Chem. J.*, **22**, 89 (1899).

³⁴⁰ Hill and Hale, *Am. Chem. J.*, **33**, 1 (1905).

³⁴¹ Hill, *Ber.*, **33**, 1241 (1900).

³⁴² Prelog and Wiesner, *Helv. Chim. Acta*, **30**, 1465 (1947).

³⁴³ Prelog, Wiesner, Ingold, and Haefliger, *Helv. Chim. Acta*, **31**, 1325 (1948).

the Michael reactions. Formally, the addition of the donor takes place in the γ,δ and α,ξ positions of the activated unsaturated system, respectively.³⁴⁴

It appears that the S—O bond in sulfoxides and sulfones (Table XX) has sufficient double bond character to conjugate with and activate neighboring ethylenic double bonds.³⁴⁵⁻³⁵⁴ In this respect, it is recalled that 1,2-bis(arylsulfonyl)ethenes are highly active dienophiles,³⁵⁵ and that vinyl sulfones add aromatic hydrocarbons in the presence of aluminum chloride in the same manner as do α,β -unsaturated ketones.³⁵⁶ Organo-magnesium and organolithium compounds also add 1,4 to α,β -unsaturated sulfones.³⁵⁷

Table XX also includes the Michael reactions of N,N-diethylvinylsulfonamide³⁵⁸ and the interesting condensations of vinyldimethylsulfonium bromide with ethyl acetoacetate and diethyl malonate.²²

Reactions involving diethyl vinylphosphonate, $\text{CH}_2=\text{CHPO}(\text{OC}_2\text{H}_5)_2$, a newly discovered type of acceptor in the Michael reaction, are listed in Table XXI. It has already been pointed out (p. 204) that compounds containing phosphono groups have sufficiently active hydrogen atoms to serve as donors in the Michael condensation. The reaction referred to here leads to the supposition that the P—O bond, like the S—O bond, is able to form a conjugated system with an adjacent ethylenic linkage.

2- and 4-Vinylpyridines (Table XXI). Although practically no work appears to have been done on the ability of the open-chain system $\text{C}=\text{C}-\text{C}=\text{N}$ to undergo Michael condensations (see p. 207), the behavior of 2- and 4-vinylpyridine shows that, at least under certain conditions, this system gives typical Michael products. The reactions investigated appear in Table XXI.³⁵⁹

³⁴⁴ Dale and Strobel, *J. Am. Chem. Soc.*, **76**, 6172 (1954).

³⁴⁵ Samuel, *J. Chem. Physics*, **12**, 380 (1944); *ibid.*, **13**, 572 (1945); Bergmann and Tschudnowsky, *Ber.*, **65**, 457 (1932); Lister and Sutton, *Trans. Faraday Soc.*, **35**, 495 (1939). See, however, Arndt and Eistert, *Ber.*, **74**, 423 (1941).

³⁴⁶ Koch, *J. Chem. Soc.*, **1950**, 2892.

³⁴⁷ Karrer, Antia, and Schwyzer, *Helv. Chim. Acta*, **34**, 1392 (1951).

³⁴⁸ Varsanyi and Ladik, *Acta Chim. Acad. Sci. Hung.*, **3**, 243 (1953) [*C.A.*, **47**, 11000 (1953)].

³⁴⁹ Kloosterziel and Backer, *Rec. trav. chim.*, **72**, 185 (1953).

³⁵⁰ Zollinger, Buechler, and Wittwer, *Helv. Chim. Acta*, **36**, 1711 (1953).

³⁵¹ Bordwell and Andersen, *J. Am. Chem. Soc.*, **75**, 6019 (1953).

³⁵² Juffé, *J. Phys. Chem.*, **58**, 185 (1954).

³⁵³ Price and Morita, *J. Am. Chem. Soc.*, **75**, 4747 (1953).

³⁵⁴ Price and Gilis, *J. Am. Chem. Soc.*, **75**, 4750 (1953).

³⁵⁵ Truce and McManis, *J. Am. Chem. Soc.*, **75**, 1672 (1953).

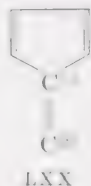
³⁵⁶ Truce, Simms, and Hill, *J. Am. Chem. Soc.*, **75**, 5411 (1953).

³⁵⁷ Potter, *J. Am. Chem. Soc.*, **76**, 5472 (1954).

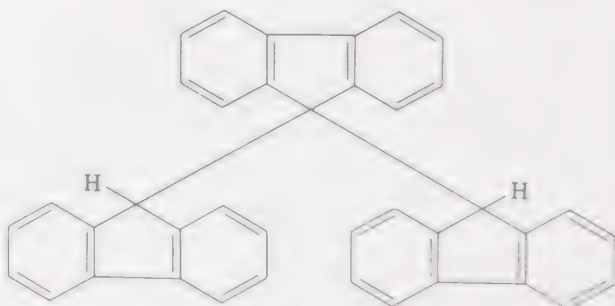
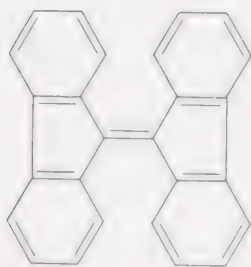
³⁵⁸ Buess and Jones, *J. Am. Chem. Soc.*, **76**, 5558 (1954).

³⁵⁹ For the addition of enolizable hydrogen compounds to the $\text{C}=\text{N}$ double bond itself, see Lazzareschi¹⁵² and Philpott and Jones.¹⁵¹

Fulvenes. Calculations as well as physical and chemical evidence have shown that the fulvenes, represented by the formula LXX, possess a polar double bond.^{360,361} It is, therefore, not surprising that fulvenes are



also acceptors in the Michael condensation. The experimental material on the subject is scanty,^{362,363} and the only donors that have been tested so far are fluorenes. Thus dibiphenyleneethylene (LXXI) adds fluorene under the catalytic influence of sodium hydroxide, to give an 82% yield



of tribiphenyleneethane (LXXII). The same reaction can be effected between 2,7-dibromofluorene and 2,7,2',7'-tetrabromodibiphenyleneethylene.

It is to be expected that these highly substituted systems will show a considerable tendency to dissociate (in the way that decaphenylbutane dissociates into pentaphenylethyl).³⁶⁴ Thus one can explain the observation that 9-aminofluorene (LXXIII) reacts with dibiphenyleneethylene (LXXIV) in the presence of ammonia to give dibiphenyleneethane (LXXV) and fluorenone imide (LXXVI) by the accompanying equation. 9-Fluorenol behaves analogously. The observation that 2,7,2',7'-tetrabromodibiphenyleneethylene and fluorene yield the dibromo derivative

³⁶⁰ Pullman, Berthier, and Pullman, *Bull. soc. chim. France*, **1950**, 1097.

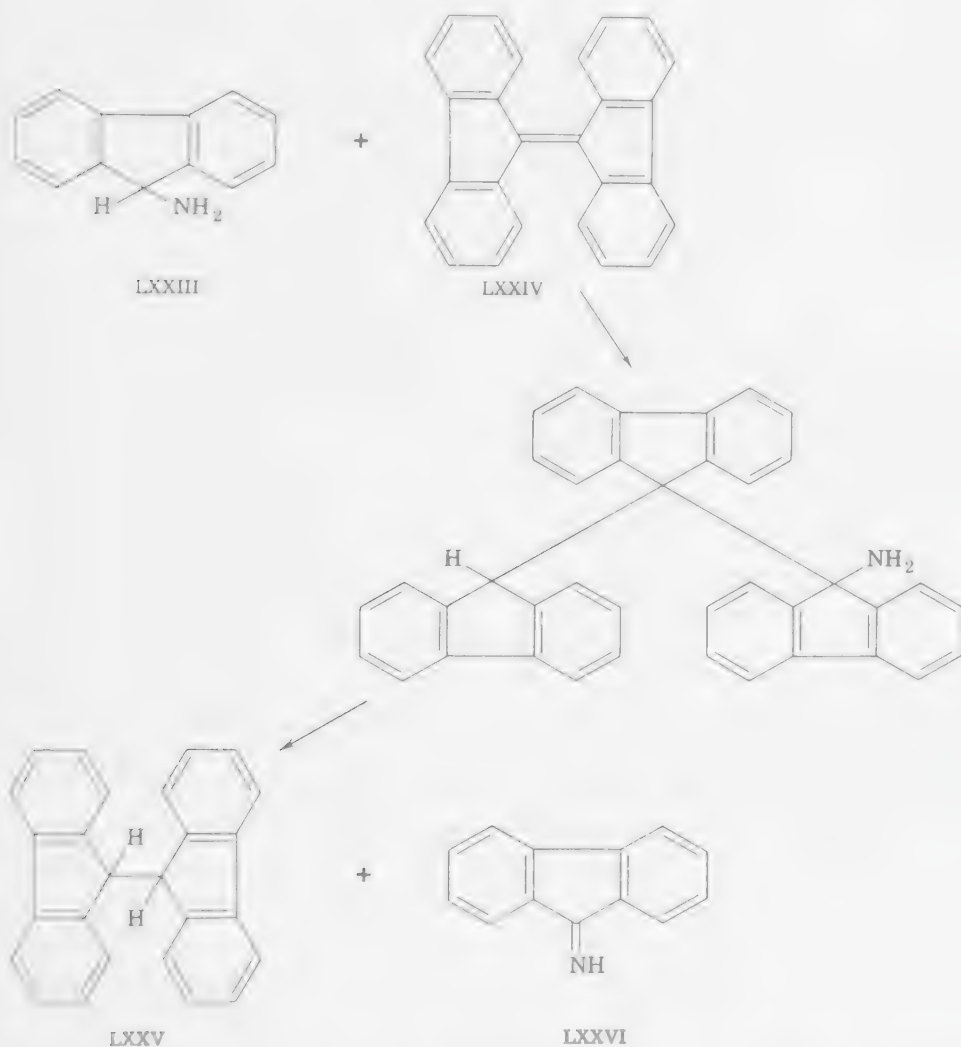
³⁶¹ Bergmann and Fischer, *Bull. soc. chim. France*, **1950**, 1084.

³⁶² Pinck and Hilbert, *J. Am. Chem. Soc.*, **68**, 2014 (1946).

³⁶³ Pinck and Hilbert, *J. Am. Chem. Soc.*, **68**, 2739 (1946).

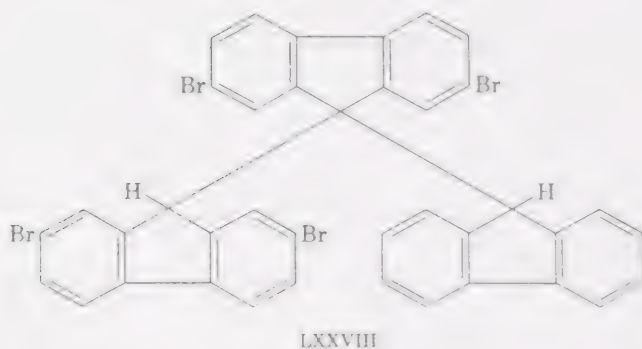
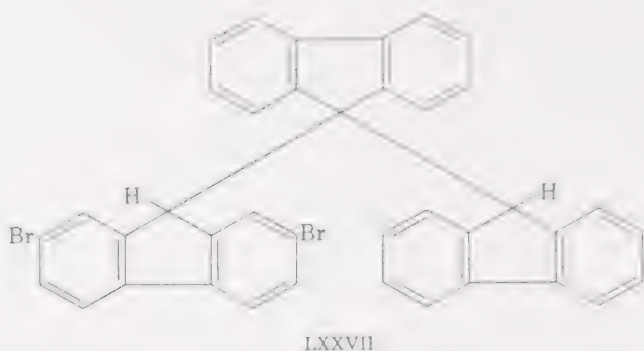
³⁶⁴ Schlenk and Mark, *Ber.*, **55**, 2296 (1922).

(LXXVII) and 2,7-dibromofluorene can be understood on the basis of a sequence of condensation and disproportionation steps.



2,7-Dibromofluorene and dibiphenylene give with sodium ethoxide as catalyst a 58% yield of α -(2,7-dibromobiphenylene)- β,γ -dibiphenylpropane (LXXVII), whereas, in the presence of potassium hydroxide and pyridine, α,β -bis-(2,7-dibromobiphenylene)- γ -biphenylpropane (LXXVIII) is formed. Thermal decomposition of these two compounds gives inter alia, 2,7-dibromodibiphenylene, 2,7-dibromodibiphenylacethane, 2,7,2',7'-tetrabromodibiphenylene, and 2,7,2',7'-tetrabromodibiphenyleneethane (formulas on p. 244).

The second solvent derivative that has been employed as an acceptor



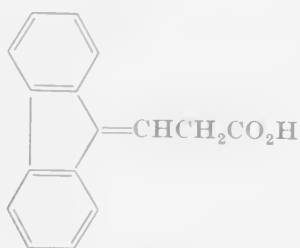
in the Michael condensation is benzylidenefluorene (LXXIX), which adds fluorene in 70% yield under the influence of a mixture of pyridine and aqueous sodium hydroxide. In accordance with the direction of the dipole moment in the semicyclic double bond of the fulvenes, the product is α,γ -dibiphenylene- β -phenylpropane (LXXX).³⁶⁵



It is not surprising that formylfluorene, i.e., η -hydroxymethylene-fluorene, is also capable of undergoing the Michael condensation (see pp. 231, 235). Formylfluorene has been converted by reaction with malonal-

³⁶⁵ Bergmann and Lavie, *J. Am. Chem. Soc.*, **74**, 3173 (1952).

acid (with loss of water and carbon dioxide) to β -(9-fluorenylidene)-propionic acid (LXXXI) in 11% yield.³⁶⁶



LXXXI

Systems That Did Not Undergo Condensation

The following is a list of reactant systems that have not given Michael condensation products. The listing is in order of increasing number of carbon atoms in the acceptor.

Acrylonitrile and diethyl acetosuccinate.³⁶⁷

Methyl vinyl sulfone and ethyl phenylacetate, acetophenone, or benzyl *p*-tolyl sulfone.¹¹⁸

Methyl vinyl ketone and "Inhoffen's ketone."³⁶⁸

Methyl isopropenyl ketone and cyclopentanone.³⁶⁹

Acetylacetone and chloroacetamide, phenylacetamide, benzyl cyanide,³⁷⁰ or α -cyanopropionamide.³⁷¹

Ethyl acrylate and 3-acetyloxindole or 1-methyl-3-acetyloxindole.³⁷²

Methyl crotonate and nitropropane in the presence of diethylamine.³⁷³

Mesityl oxide and 2-quinaldine.³⁷⁴

Crotonaldehyde with *N*-(1,3-dimethylbutylidene)-1,3-dimethylbutylamine.³⁷⁵

Ethyl crotonate and 2,7-dibromofluorene.³⁷⁶

p-Benzoquinone and ethyl *N*-acetyl- β -aminocrotonate or diethyl aminomethylenemalonate.³⁷⁷

³⁶⁶ Borsche and Niemann, *Ber.*, **69**, 1993(1936).

³⁶⁷ Blood and Linstead, *J. Chem. Soc.*, **1952**, 2255.

³⁶⁸ Pinder and Robinson, *J. Chem. Soc.*, **1952**, 1224.

³⁶⁹ Colonge and Dreux, *Bull. soc. chim. France*, **1952**, 47.

³⁷⁰ Basu, *J. Indian Chem. Soc.*, **7**, 815 (1930) [*C.A.*, **25**, 1528 (1931)].

³⁷¹ Bardhan, *J. Chem. Soc.*, **1929**, 2223.

³⁷² Juhari and Printy, *J. Am. Chem. Soc.*, **75**, 5301 (1953).

³⁷³ Klotzel, *J. Am. Chem. Soc.*, **70**, 3571 (1948).

³⁷⁴ Weiss and Hauser, *J. Am. Chem. Soc.*, **71**, 2026 (1949).

³⁷⁵ Smith, Norton, and Ballard, *J. Am. Chem. Soc.*, **75**, 3316 (1953).

³⁷⁶ Taylor and Connor, *J. Org. Chem.*, **6**, 696 (1941).

³⁷⁷ Beer, Davenport, and Robertson, *J. Chem. Soc.*, **1953**, 1262.

- 3-Methyl-2-cyclopentenone and ethyl acetoacetate.³⁷⁸
 Ethyl α -acetamidoacrylate and oxindole.³⁷⁹
 1-Acetylcyclohexene and 6-methoxy-9-methyl-1-keto-1,4,5,6,7,8,9,10-octahydronaphthalene.³⁸⁰
 Methyl 5-methyl-2-hexenoate or δ -methylsorbate with dimethyl malonate or methyl cyanoacetate.³⁸¹
 1-Acetyl-2-methylcyclohexene with various reagents.³⁸²⁻³⁸⁷
 Trimethylquinone and biacetyl or its half-acetal.³⁸⁸
 Methyl α -cyano- β -methylsorbate and methyl cyanoacetate.³⁸¹
 Ethyl β -diethylaminovinyl ketone and 2-methylcyclohexanone.³⁸⁹
 Trimethylquinone monomethylimine and 3,3-dimethoxy-2-butanone.³⁸⁸
 Methyl 2-hydroxystyryl ketone and ethyl oxaloacetate, ethyl cyanoacetate, or diethyl malonate.³⁸
 Methyl α -cyclohexylideneethyl ketone with diethyl malonate.³⁹⁰
 4-Phenyl-2-methylamino-2-buten-4-one and ethyl cyanoacetate.³⁹¹
 Diethyl 1-pentene-1,3-dicarboxylate and ethyl cyanoacetate.³⁹²
 Ethyl cinnamate or diethyl benzylidenemalonate and fluorene or 2,7-dibromofluorene.³⁷⁶
 Diethyl 2-acetyl-2-hexene-1,6-dioate and 1-tetralone or 6-methoxy-1-tetralone.^{206,393}
 2-Dimethylamino- or 2-morpholino-benzosuberone or their methiodides with biacetyl or its monoxime.³⁹⁴
 3-Phenyl-5,5-dimethyl-2-cyclohexenone and diethyl malonate, ethyl cyanoacetate, or nitromethane.³⁹⁵
 3-Benzylidene-6-formylcyclohexanone and 5-diethylaminopentane-2,3-dione-3-monoxime or its methiodide.³⁹⁴

³⁷⁸ Acheson, *J. Chem. Soc.*, **1952**, 3415.

³⁷⁹ Julian, Printy, Ketcham, and Doone, *J. Am. Chem. Soc.*, **75**, 5305 (1953).

³⁸⁰ Nazarov and Zav'yalov, *Izvest. Akad. Nauk S.S.S.R. Otdel. Khim. Nauk*, **1952**, 437 [*C.A.*, **47**, 5365 (1953)].

³⁸¹ Reid and Sause, *J. Chem. Soc.*, **1954**, 516.

³⁸² Bagehi and Banerjee, *J. Indian Chem. Soc.*, **23**, 397 (1946) [*C.A.*, **42**, 1601 (1948)].

³⁸³ Dimroth, *Angew. Chem.*, **59**, 215 (1947).

³⁸⁴ Huber, *Ber.*, **71**, 725 (1938).

³⁸⁵ Johnson, Szmuszkowicz, and Miller, *J. Am. Chem. Soc.*, **72**, 3726 (1950).

³⁸⁶ Ludevitz, Dissertation, Goettingen, 1944.

³⁸⁷ Turner and Voitle, *J. Am. Chem. Soc.*, **72**, 4166 (1950).

³⁸⁸ Smith and Dale, *J. Org. Chem.*, **15**, 832 (1950).

³⁸⁹ Hills and McQuillin, *J. Chem. Soc.*, **1953**, 4060.

³⁹⁰ Kon, *J. Chem. Soc.*, **1926**, 1792.

³⁹¹ Basu, *J. Indian Chem. Soc.*, **12**, 299 (1935) [*C.A.*, **29**, 6878 (1935)].

³⁹² Thorpe and Wood, *J. Chem. Soc.*, **103**, 1579 (1913).

³⁹³ Peak, Robinson, and Walker, *J. Chem. Soc.*, **1936**, 752.

³⁹⁴ Tarbell, Wilson, and Ott, *J. Am. Chem. Soc.*, **74**, 6263 (1952).

³⁹⁵ Woods, *J. Am. Chem. Soc.*, **69**, 2549 (1947).

Benzylidenacetophenone and diethyl cyanomalonate,¹²⁵ diethyl ethylmalonate,³⁶⁶ diethyl butylmalonate,¹²⁵ or diethyl phenylmalonate,¹²⁵

m- or *p*-Nitrobenzylidenacetophenone and fluorene.³⁷⁶

α -Cyanostilbene and ethyl phenylacetate.⁸²

Diethyl cumamylidenemalonate and methyl cyanoacetate.³⁹⁷

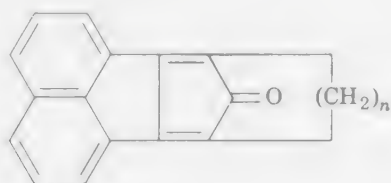
cis-Dibenzoylethylene and diethyl benzylmalonate.⁵⁸

2-Acetyl-1,3-diphenyl-2-propen-1-al and ethyl tetrahydroanthranilate.³⁹⁸

Ethyl 2,4-diphenylbutadiene-1-carboxylate and ethyl cyanoacetate.³⁹⁷

2-(Trimethylquinonyl)methylene-3,5,6-trimethyl-2-acetoxy- (or methoxy-1,3,5-cyclohexadienone with diethyl malonate or ethyl cyanoacetate.³⁹⁹

Unsaturated carbonyl-bridged system such as



with diethyl malonate or cyanoacetamide.⁴⁰⁰

Diethyl benzylidenemalonate and nitroethane.⁸⁶

2,3-Dichloro-1,4-naphthoquinone and acetone.²⁷³

Mesityl oxide and cyclohexanone.⁴⁰¹

Acrylonitrile and diethyl trimethylsuccinate, which appears to give an O-substituted derivative of the enol form.⁴⁰²

3-Methyl-4-amino-3-penten-2-one and cyanoacetamide.³⁹⁸

2-Methylcycloheptylideneacetonitrile and cyanoacetamide.^{402a}

Examination of these examples does not lead to definite conclusions as to the factors responsible for the failure of the condensation. However, the qualitative impression gained is that many substituents about the reacting centers tend to prevent the reaction. In the donors, this can be ascribed to lowering acidity, but steric factors undoubtedly also play a part in interfering with the condensation. As a case in point, the failure of diethyl phenylmalonate to undergo any Michael reaction⁴⁰³ may be cited.

³⁹⁶ de Benneville, Clagett, and Connor, *J. Org. Chem.*, **6**, 690 (1941).

³⁹⁷ Bloom and Ingold, *J. Chem. Soc.*, **1931**, 2765.

³⁹⁸ Basu, *J. Indian Chem. Soc.*, **8**, 319 (1931) [*C.A.*, **26**, 458 (1932)].

³⁹⁹ Smith, Davis, Jr., and Sogn, *J. Am. Chem. Soc.*, **72**, 3651 (1950).

⁴⁰⁰ Allen and Van Allan, *J. Org. Chem.*, **18**, 882 (1953).

⁴⁰¹ Braude and Wheeler, *J. Chem. Soc.*, **1955**, 329.

⁴⁰² Talukdar and Bagechi, *J. Org. Chem.*, **20**, 13 (1955).

^{402a} Kandish and Linstead, *J. Chem. Soc.*, **1929**, 2139.

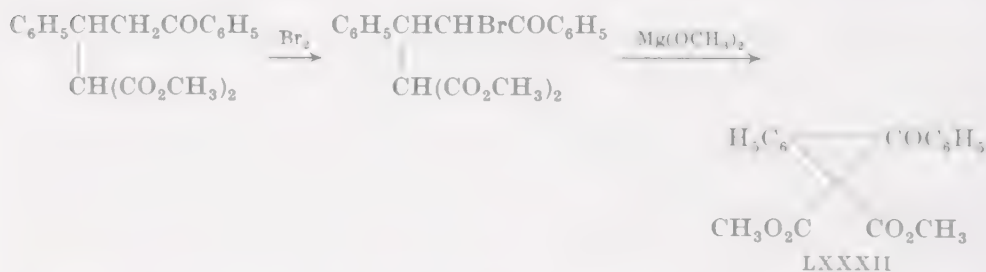
⁴⁰³ Connor, *J. Am. Chem. Soc.*, **55**, 4597 (1933).

SYNTHETIC APPLICATIONS

Certain products of the Michael condensation may be used for the preparation of amino acids; others may undergo spontaneous cyclization or cycloisomerization reactions and thus open routes to a variety of ring compounds. In particular, the Robinson modification of the Michael reaction has been utilized for the synthesis of alicyclic ring systems (Table VIII). It seems, therefore, desirable to give a systematic picture of these synthetic possibilities.

Synthesis of Cyclic Systems

Cyclopropane Rings. Compounds that serve as intermediates for the formation of products containing the cyclopropane ring can be obtained by Michael condensation. For example, the product of the Michael reaction between benzylideneacetophenone and dimethyl malonate can be brominated and dehydrobrominated to yield a cyclopropane



derivative (LXXXII), as shown in the formulation.⁴⁰⁴ Many highly substituted cyclopropane derivatives can be prepared by this route.

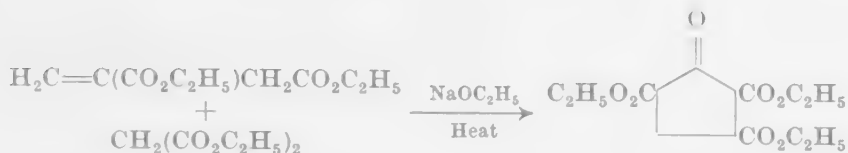
Cyclobutane Rings. It has been reported that cyclobutane derivatives were formed by intramolecular Michael condensation of esters of certain polycarboxylic acids.^{322,323,405} Recent investigations^{324,325} have shown, however, that reaction of diethyl acetylenedicarboxylate with, for example, tetraethyl ethane-1,1,2,2-tetracarboxylate does not give hexaethyl cyclobutane-1,2,3,3,4,4-hexacarboxylate but hexaethyl butene-1,1,2,2,3,4-hexacarboxylate.

Cyclopentane Rings. Cyclopentanone derivatives are formed *in situ* by Dieckmann condensation of the primary adducts of the Michael condensation between ethyl itaconate (or itaconate) and malonates or

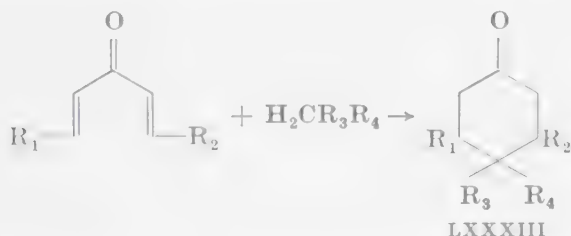
⁴⁰⁴ Kohler and Conant, *J. Am. Chem. Soc.*, **39**, 1404 (1917).

⁴⁰⁵ Guthzeit, Weiss, and Shaefer, *J. prakt. Chem.*, [2], **80**, 393 (1909).

substituted malonates.^{6,145,406} (Compare also the analogous formation of cyclopentanones from cyclopropane derivatives; see pp. 205-207).



Cyclohexane and Condensed Alicyclic Ring Systems. Divinyl ketones of the dibenzylideneacetone type react with donors that contain an active methylene group according to the accompanying general equation, yielding substituted cyclohexanones (LXXXIII).¹⁹⁸⁻²⁰⁰



In general, Michael adducts of unsaturated aldehydes and ketones with ethyl acetoacetate easily undergo a secondary condensation between the terminal methyl group of the adduct and the carbonyl group of the original acceptor molecule. In a fair number of cases, this cyclization reaction is accompanied by the elimination of the carbethoxy group. This reaction is illustrated by the synthesis of the keto esters LXXXIV,²²⁹ LXXXV,^{15,16,17} and LXXXVI.⁴⁰⁷ In the last example, the reaction stops at the intermediary aldol stage, without the additional dehydration step⁴⁰⁸ (see equations on p. 250).

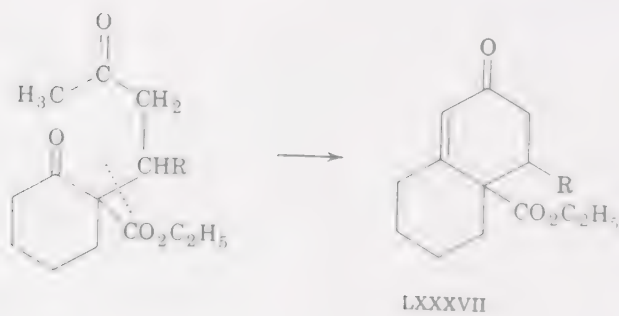
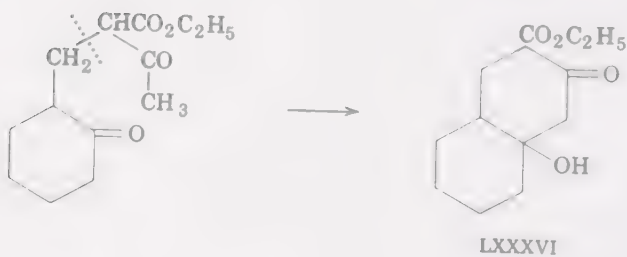
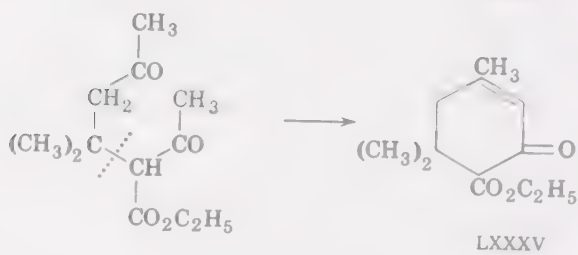
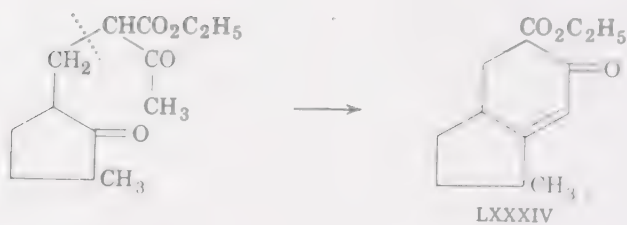
Obviously, the same reaction will take place whenever 1,5-diketones of the above type are formed, e.g., in the condensation product of ethyl cyclohexanone-2-carboxylate and ethylideneacetone or benzylideneacetone, yielding LXXXVII ($\text{R} = \text{CH}_3$ or C_6H_5).⁴⁰⁹ A similar cyclization takes place with the adduct of 1-tetralone and ethylideneacetoacetate or

¹⁹⁸ Tuovinen, Iittu, Salmio, and Kuusinen, *Suomen Kemistilehti*, **8B**, 46 (1935) [*C.A.*, **30**, 2185 (1936)].

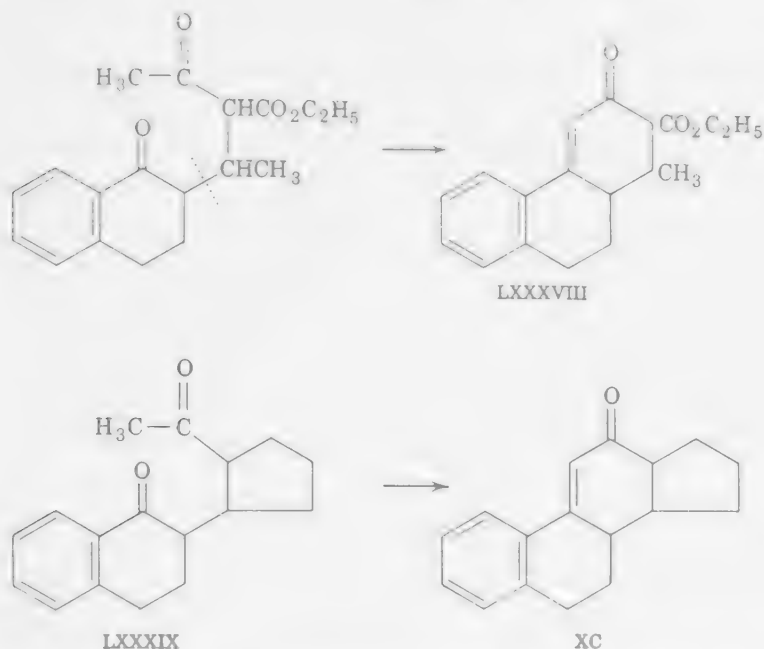
⁴⁰⁷ Mannich, Koch, and Borkowsky, *Ber.*, **70**, 355 (1937).

⁴⁰⁸ In this and the following formulations, the dotted lines indicate the components from which the starting materials of the cyclization reaction are formed.

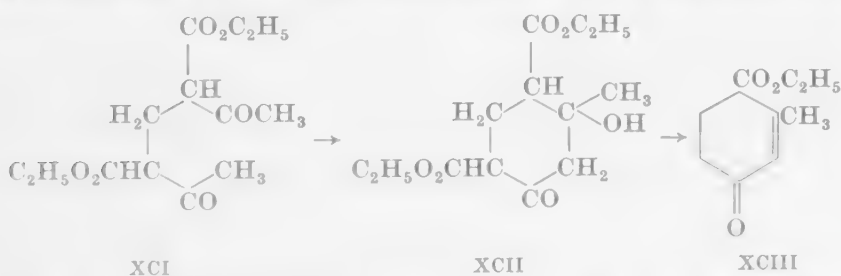
⁴⁰⁹ Rapson, *J. Chem. Soc.*, **1936**, 1626.



acetylcyclopentene, yielding the tricyclic keto ester LXXXVIII²⁰⁶ and (via LXXXIX) the tetracyclic ketone XC.⁹⁸ respectively.



A related reaction is the cyclization of diethyl alkylidenebisacetoacetates. Diethyl methylenebisacetoacetate (XCI), for example, forms XCII: this then loses water and one carboethoxyl group to give the "Hagemann ester" XCIII. In other instances, both carboethoxy groups



are split off and 1-methyl-5-alkyl-1-cyclohexen-3-ones are formed. The reaction of ethyl sodioacetoacetate and ethyl ethoxymethyleneacetoacetate is more complicated.⁴¹⁰⁻⁴¹³ Other examples are the condensation products of mesityl oxide and ethyl benzoylacetate,⁴¹⁴ acetylacetone,⁴¹⁵

⁴¹⁰ Claisen, *Ann.*, **297**, 1 (1897), especially p. 49.

⁴¹¹ Liebermann, *Ber.*, **39**, 2071 (1906), and previous papers.

⁴¹² Feist, Delfs, and Langenkamp, *Ber.*, **59**, 2958 (1926).

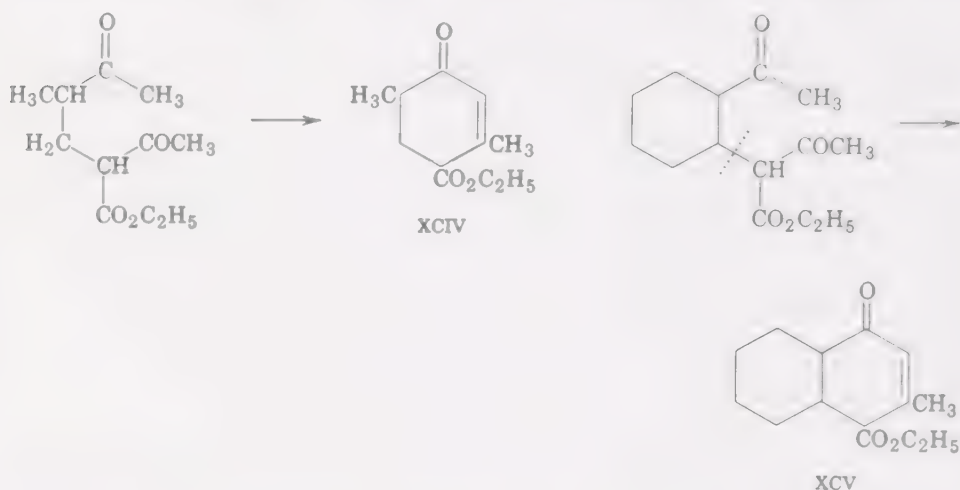
⁴¹³ Feist, Janssen, and Chen, *Ber.*, **60**, 199 (1927).

⁴¹⁴ Beringer and Kuntz, *J. Am. Chem. Soc.*, **73**, 364 (1951).

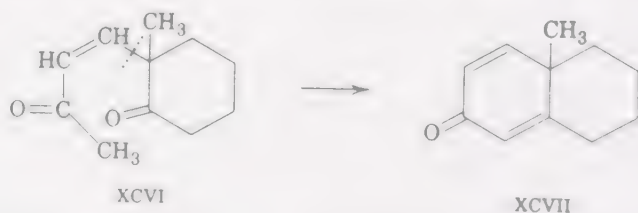
⁴¹⁵ Scheiber and Meisel, *Ber.*, **48**, 238 (1915).

or deoxybenzoin;⁴¹⁶ the 1:2 adducts of diethyl malonate or its mono-substitution products with acrolein and methacrolein;⁴¹⁷ and the condensation products of methyl vinyl ketone with 2-methylcyclopentanone,^{229,230} 2-methylcyclohexanone,²²⁹ or aliphatic ketones.^{418,419}

There are a few cases in which the methyl of an acetyl group other than that of the ethyl acetoacetate component supplies the hydrogen for the water molecule to be eliminated, e.g., in the formation of the cyclohexenones XCIV⁴²⁰ and XCV.⁹³ This cyclization is also possible with



unsaturated 1,5-diketones. Obviously, the configuration of the double bond must be *cis* for cyclization to take place. The product XCVI from acetylacetylene and 2-methylcyclohexanone gives the dienone XCVII.



A meta ring is alleged⁴²¹ to be formed from caryone and ethyl acetoacetate.

The addition products of diethyl malonate and α,β -ethylenic non-aromatic ketones are δ -keto esters, which can cyclize by elimination of

⁴¹⁶ Ionescu and Popescu, *Bull. soc. chim. France*, **51**, 1215 (1932).

⁴¹⁷ Warner and Moe, U.S. pat. 2,575,376 [*C.A.*, **46**, 5082 (1952)].

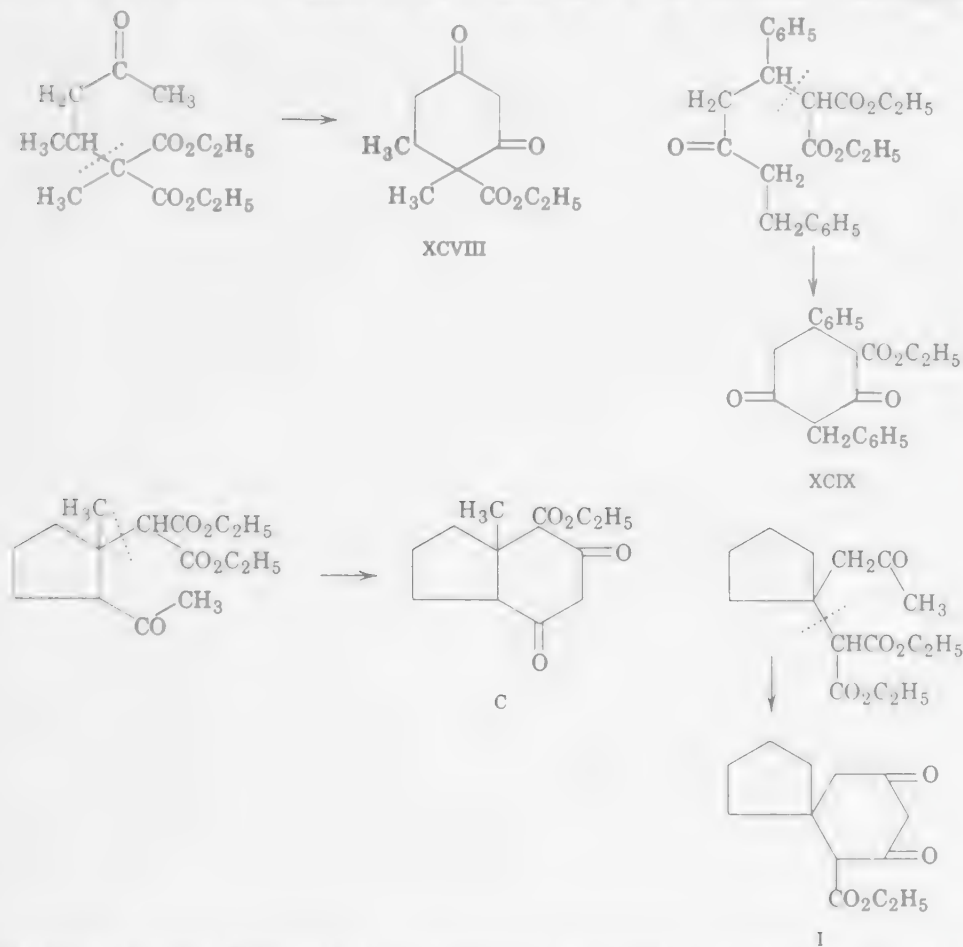
⁴¹⁸ Colonge and Dreux, *Compt. rend.*, **231**, 1504 (1950).

⁴¹⁹ Ebel and Pesta, Ger. pat. 714,314 [*C.A.*, **38**, 1754 (1944)].

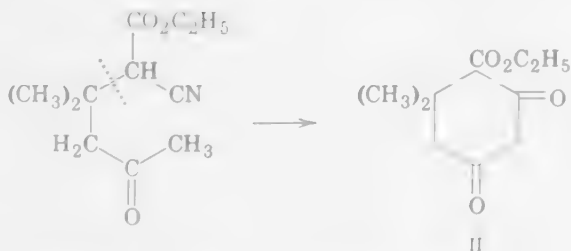
⁴²⁰ Décombe, *Compt. rend.*, **205**, 680 (1937).

⁴²¹ Rabe and Weiling, *Ber.*, **36**, 227 (1903).

an alkoxy group and a hydrogen atom in the ϵ position. Cyclic 1,3-diones, such as XCVIII,⁴²² XCIX,⁴²³ C,⁴²⁴ and I,^{424,*} are formed. Analogous



adducts derived from ethyl cyanoacetate (instead of malonate) give the same final products, e.g., the cyclohexanedione II.⁴²⁵



⁴²² Hinkel, Ayling, Dippy, and Angel, *J. Chem. Soc.*, **1931**, 814.

⁴²³ Mattar, Hastings, and Walker, *J. Chem. Soc.*, **1930**, 2455.

⁴²⁴ Chuang, Ma, and Tien, *Ber.*, **68**, 1946 (1935).

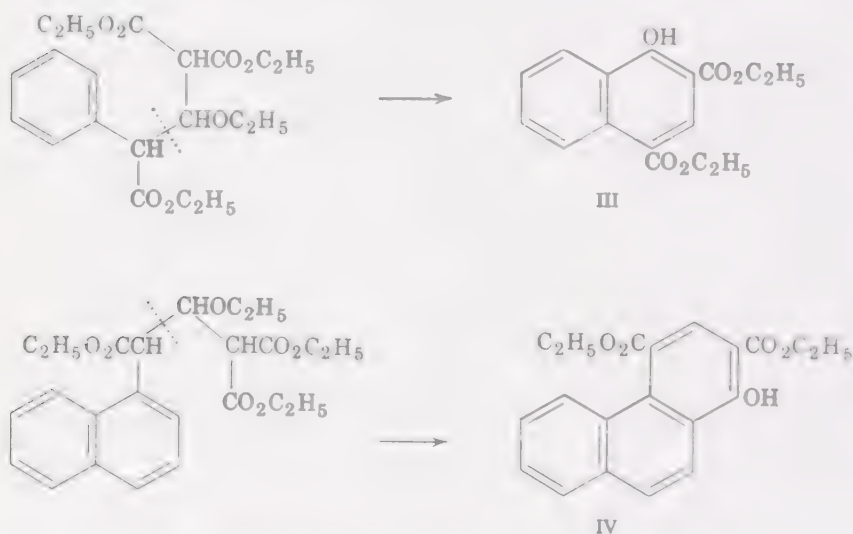
* Enumeration of formulas begins with I again after C to reduce the complexity of the numbers.

⁴²⁵ Vorländer, *Ann.*, **294**, 253 (1897).

Analogous behavior has, of course, been observed with the δ -keto esters formed, for example, from β -keto esters and α,β -ethylenic esters.⁴²⁶

Aromatic Ring Systems. When the δ -keto ester contains a double bond in the β,γ position, the final product is a substituted resorcinol; thus the adduct of diethyl malonate and *n*-butylacetylacetylene gives 5-*n*-butylresorcinol (see p. 214). Other reaction schemes in which aromatic products are formed in the Michael condensation are described in the remaining paragraphs of this section.

Esters of styrylacetic acid, which can be obtained from arylacetates and diethyl ethoxymethylenemalonate, cyclize to derivatives of α -naphthol (III)³⁰⁸ or hydroxyphenanthrene IV.³⁰⁹ Similarly, the condensation of the enolic forms of β -keto aldehydes and β -diketones with diethyl



acetone-1,3-dicarboxylate (V)^{427,428} leads directly to aromatic compounds. Ethyl acetoacetate can take the place of diethyl acetone-1,3-dicarboxylate in this process.⁴²⁷ Analogously, the enol form of nitromaleimidealdehyde (VI) reacts with ketones that can act as dimers in the Michael reaction^{111,339,343} (equations on p. 255).

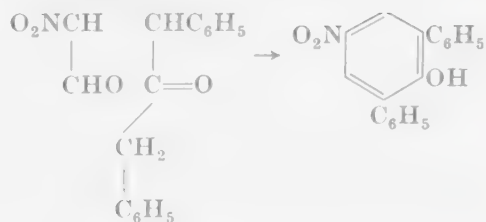
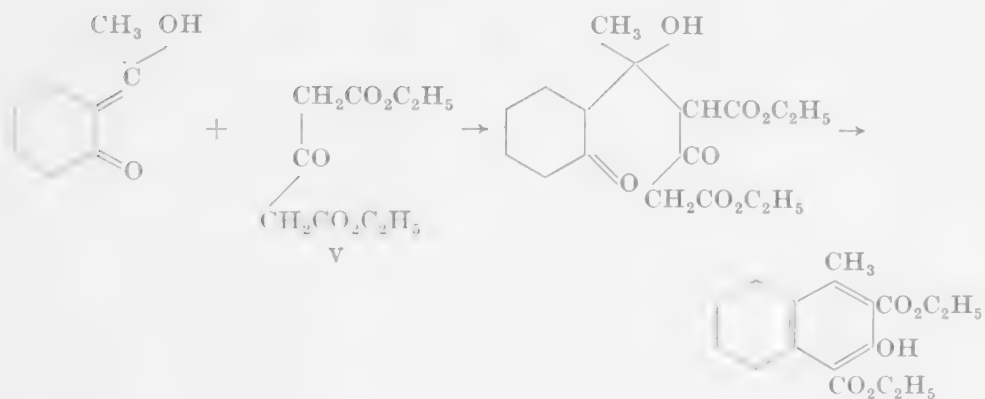
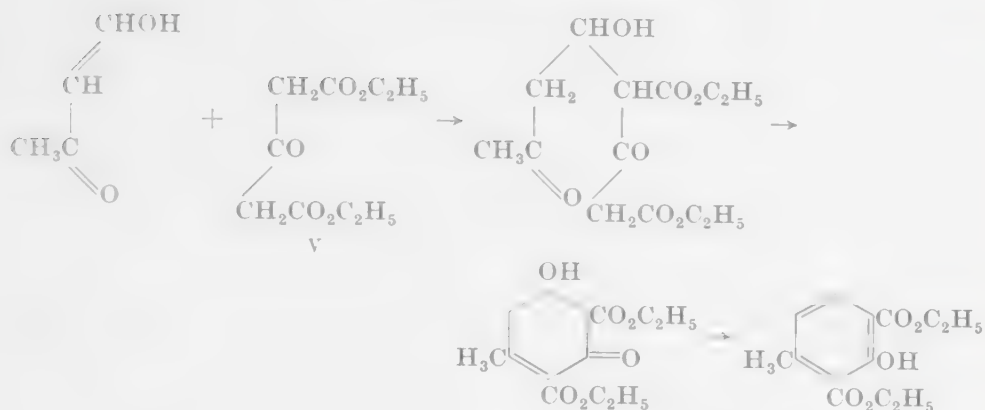
A somewhat more complicated reaction takes place when formaldehyde is condensed with diethyl malonate.⁴²⁹ The diethyl ethylenedioxydicarboxylate (VIII) first formed condenses with diethyl malonate to glycerotetraethyl methylenobismalonate (VII), and this with another molecule

³⁰⁸ Papadakis and Scigliano, *J. Am. Chem. Soc.*, **73**, 5483 (1951).

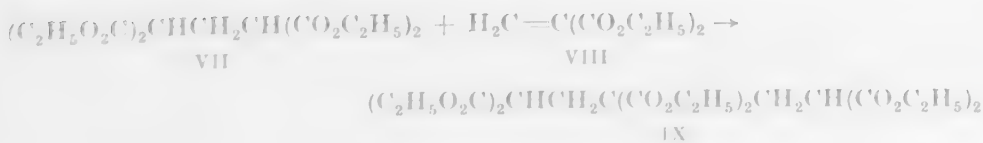
³⁰⁹ Prelog, Metzler, and Jeger, *Helv. Chim. Acta*, **30**, 675 (1947).

⁴²⁷ Prelog, Ruzicka, and Metzler, *Helv. Chim. Acta*, **30**, 1883 (1947).

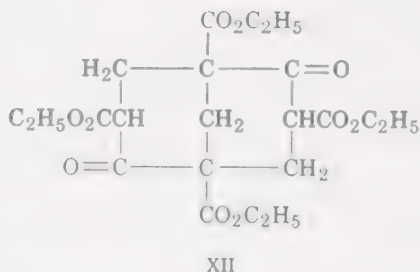
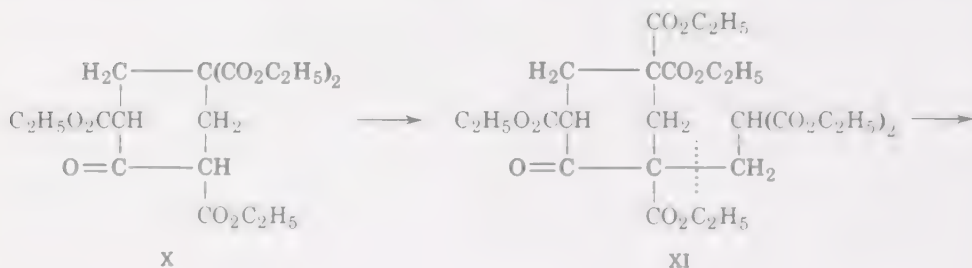
⁴²⁸ Meerwein and Schuermann, *Ann.*, **398**, 196 (1913), especially p. 223; Meerwein and Schuermann, *Monatsh. Chem.*, **47**, 104, 161 (1916).



of diethyl ethylene 1,1-dicarboxylate yields hexaethyl pentane-1,1,3,3,5,5-hexacarboxylate (IX). Cyclization of IX, by a Dieckmann reaction and

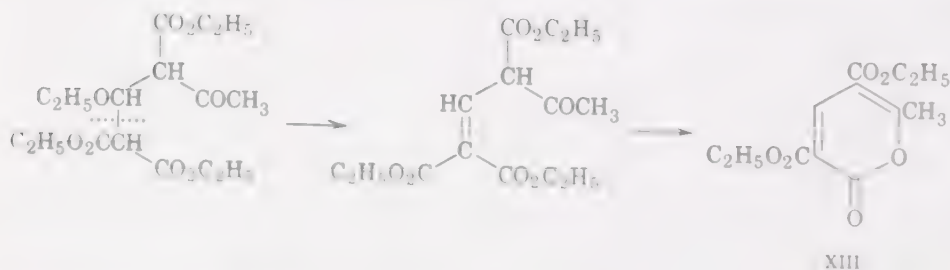


loss of one carbethoxy group beta to the keto group, leads to tetraethyl cyclohexanone-2,4,4,6-tetracarboxylate (X). This can again undergo a Michael reaction with diethyl ethylene-1,1-dicarboxylate to give XI. Renewed Dieckmann reaction and loss of a carbethoxy group yields as



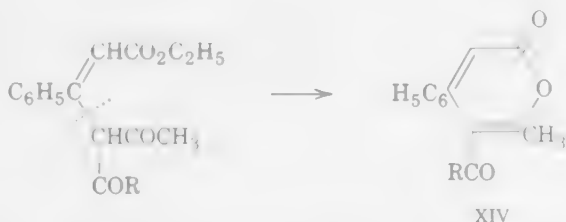
the final product tetraethyl bicyclo[3.3.1]nonane-2,6-dione-1,3,5,7-tetracarboxylate (XII).

Oxygen-Containing Rings. δ -Keto esters containing a double bond in the α,β position cyclize by an entirely different course from their β,γ analogs. Thus, although the β,γ compounds form 5-alkylresorcinols (see p. 214), the adducts of diethyl malonate and hydroxymethylene ketone

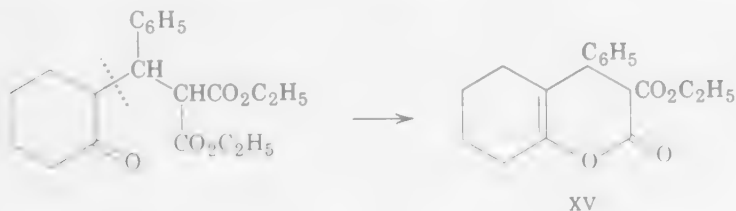


derivatives lose water or ethanol in the course of condensation, and α -pyrone derivatives such as XIII are formed. Another example is the adduct of ethyl acetoacetate and diethyl ethoxymethylene-malonate or -cyanoacetate.³¹⁰ The condensation products of ethyl phenylpropiolate

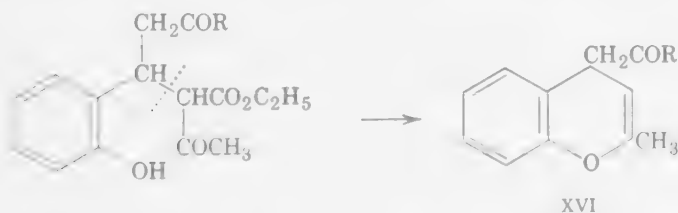
with ethyl acetoacetate^{430, 431} and acetylacetone^{432, 433} behave analogously giving XIV ($R = OC_2H_5$ and CH_3 , respectively).



An additional case, in which a saturated δ -keto ester is cyclized by enolization of the carbonyl group, is represented by the adduct of cyclohexanone and diethyl benzylidenemalonate. Here, the ε -methylene group is sterically prevented from participation in a potential ring system and the enol lactone XV is formed.



γ -(*o*-Hydroxyphenyl)ketones are converted to 2,3-benzo-1,4-dihydropyran derivatives (XVI, $R = CH_3$, C_6H_5) under the conditions of the



Michael condensation.^{293, 434} Similar ring closures have been treated in an earlier chapter of *Organic Reactions*.⁴³⁵ The adduct from 3-chloro-2-cyclohexenyl one and diethyl methylmalonate loses hydrogen chloride

⁴³⁰ Feist and Pomme, *Ann.*, **370**, 72 (1909).

⁴³¹ Ruhemann, *J. Chem. Soc.*, **75**, 245 (1899).

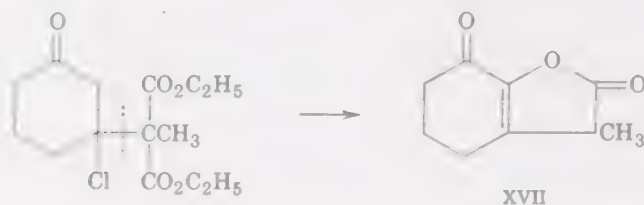
⁴³² Ruhemann, *J. Chem. Soc.*, **75**, 411 (1899).

⁴³³ Ruhemann and Cunningham, *J. Chem. Soc.*, **75**, 778 (1899).

⁴³⁴ Forster and Heilbron, *J. Chem. Soc.*, **125**, 340 (1924).

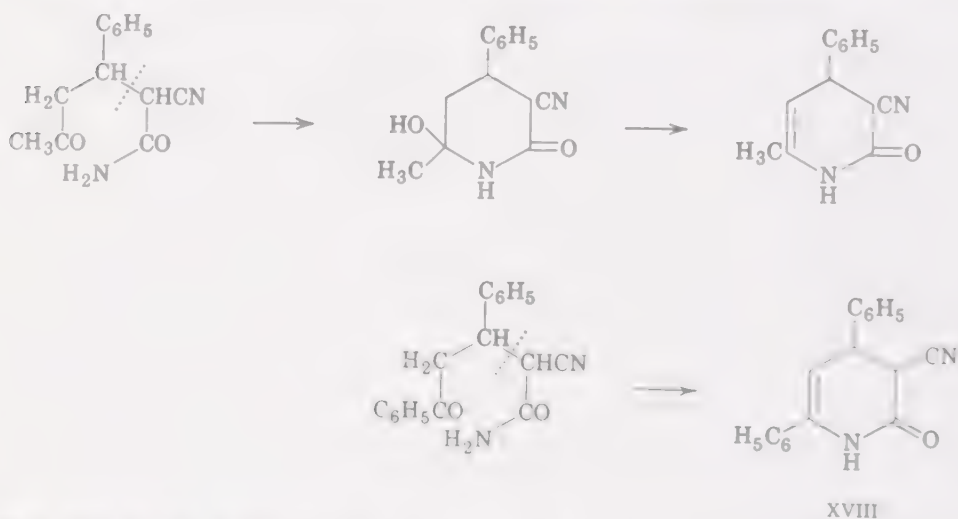
⁴³⁵ Hauser, Swamer, and Adams, in Adams, *Organic Reactions*, Vol. 8, Chapter 3, John Wiley & Sons, 1954. See especially pp. 90-95 and Tables XVI and XVII.

and cyclizes to the saturated lactone XVII.⁴³⁶ Dovey and Robinson⁴³⁷ have suggested that the formation of 2,4,6-triphenylpyrylium fluoroborate



from acetophenone and boron trifluoride takes place by a Michael reaction. However, it has recently been proved that this is not the case.⁴³⁸

Piperidines and Pyridines. δ -Ketonic amides formed by Michael condensations from cyanoacetamide and α,β -ethylenic ketones undergo cyclization to unsaturated cyano-substituted 2-ketopiperidines (XVIII).



The first of the accompanying examples shows a hydroxylated intermediate, such as has been isolated in a number of reactions.⁴³⁹

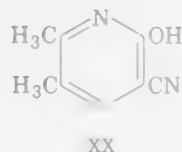
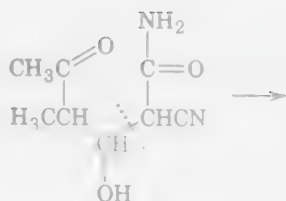
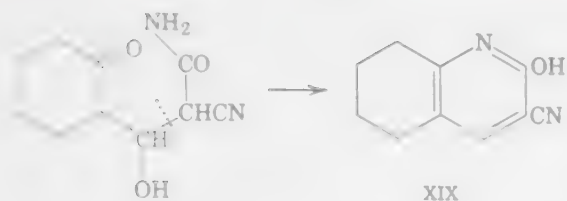
A slightly different scheme applies to the condensation products of cyanoacetamide and α -hydroxymethylene ketones, in which, by the loss of water, a second double bond is introduced into the ring and thus the aromatization to 2-hydroxypyridines (XIX and XX) is facilitated.^{440,441} Aromomethylene ketones behave analogously,⁴⁴² and cyanoacetamide can

⁴³⁶ Pearson, Friedman, Blum, and Norgum, *Current Sci. India*, **12**, 136 (1943) [*R.S.*, **37**, 6671 (1943)].

⁴³⁷ Dovey and Robinson, *J. Chem. Soc.*, **1935**, 1389.

⁴³⁸ Elderfield and King, *J. Am. Chem. Soc.*, **76**, 5437 (1954).

⁴³⁹ Barat, *J. Indian Chem. Soc.*, **7**, 321 (1930) [*C.A.*, **24**, 4786 (1930)].



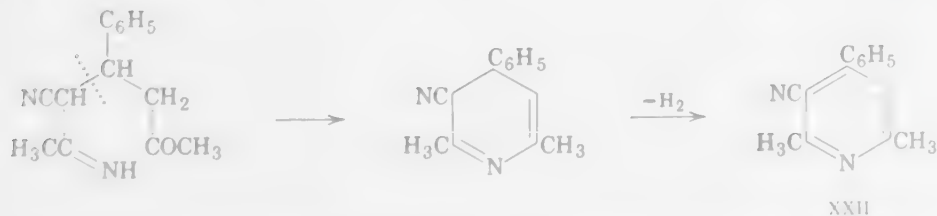
be replaced by malonamide.³⁷⁰ The same result is obtained with the adducts from cyanoacetamide and acetylenic ketones. Compounds having the general structure XXI ($R = C_2H_5$ or C_6H_5) are formed.^{181,184}



If the precursor of XXI is shown in the tautomeric form XXIA, it is evident that compounds of type XXIB will be capable of a similar

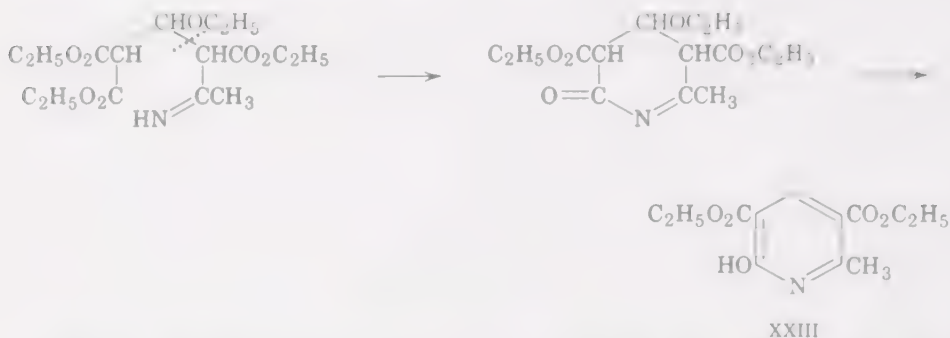


transformation into pyridine derivatives. Thus "diacetone" and benzylideneacetone give, after spontaneous loss of hydrogen from the primary product, 3-cyano-4-phenyl-2,6-dimethylpyridine (XXII).⁴⁴⁰

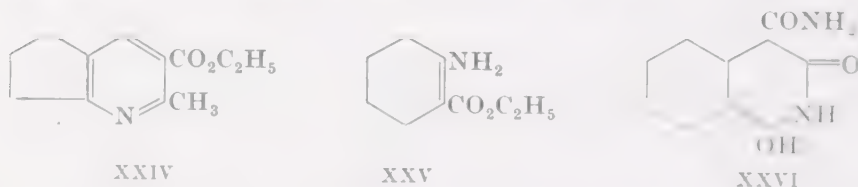


⁴⁴⁰ Chatterjee, *J. Indian Chem. Soc.*, **29**, 323 (1952) [*C.A.*, **47**, 9972 (1953)].

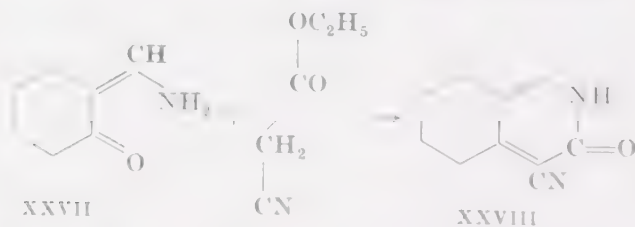
Likewise, the imine of ethyl acetoacetate condenses with diethyl ethoxymethylenemalonate with loss of ethanol to give diethyl 2-hydroxy-6-methylpyridine-3,5-dicarboxylate (XXIII).⁴⁴¹



Generally speaking, the imines of β -keto esters and β -diketones react in this manner with hydroxymethylene, alkoxyethylene, and aminomethylene ketones and esters.⁴⁴²⁻⁴⁴⁴ Thus, from 2-hydroxymethylene-cyclopentanone and ethyl iminoacetoacetate, ethyl 5-methyl-4-azaindene-6-carboxylate (XXIV) becomes available.⁴⁴⁵ Also ethyl tetrahydroanthranilate (XXV) reacts in the manner of an aminomethylene ester



giving with malonamide 1-hydroxy-3-keto-2,3,4,5,6,7,8,10-octahydroisoquinoline-4-carboxamide (XXVI).⁴⁴¹ The only exception to this rule is the reaction of 2-aminomethylenecyclohexanone (XXVII) with ethyl cyanoacetate, which is claimed⁴⁴⁶ to yield 3-keto-4-cyano-2,3,5,6,7,8-hexahydroisoquinoline (XXVIII). In this connection Berson and



⁴⁴¹ Ochiai and Ito, *Ber.*, **74**, 1111 (1941).

⁴⁴² Basu and Banerjee, *J. Indian Chem. Soc.*, **12**, 665 (1935) [*C.A.*, **30**, 2194 (1936)].

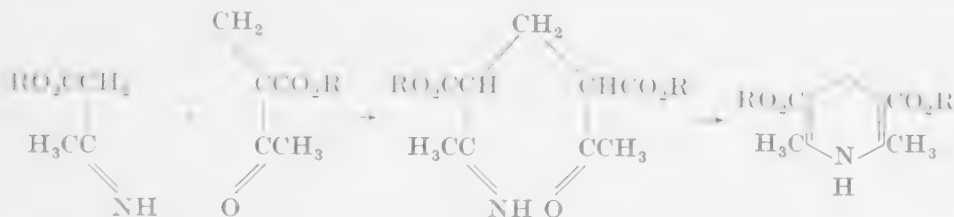
⁴⁴³ Basu, *Ann.*, **512**, 131 (1934).

⁴⁴⁴ Dornow and Machens, *Chem. Ber.*, **80**, 502 (1947).

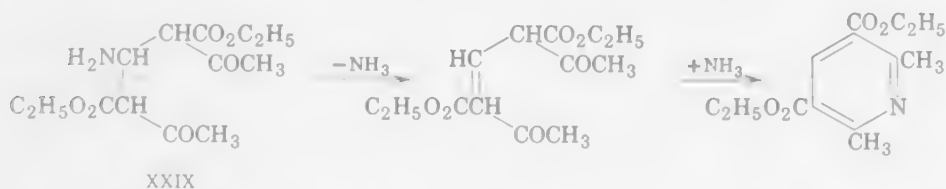
⁴⁴⁵ Basu, *Science and Culture India*, **2**, 466 (1937) [*C.A.*, **31**, 3919 (1937)].

⁴⁴⁶ Basu and Banerjee, *Ann.*, **516**, 243 (1935).

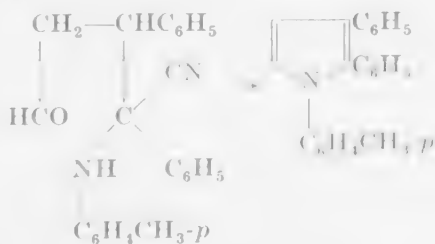
Brown⁴⁴⁷ consider that Hantzsch's synthesis of 1,4-dihydropyridines involves a Michael reaction. These authors assume that, e.g., in the condensation of formaldehyde, ammonia, and ethyl acetoacetate, ethyl β -aminocrotonate and ethyl methyleneacetoacetate are formed and then react in the following way.



Another route to the pyridine series is possible in all Michael condensations that lead to 1,5-diketones capable of being cyclized by treatment with ammonia; in these reactions ammonia can be used as the catalyst for the Michael condensation. A special example of this general possibility is provided in the reaction of ethyl aminomethyleneacetoacetate with ethyl acetoacetate or cyclohexanone;⁴⁵⁰ ammonia is eliminated from the primary product XXIX in the first step and utilized in the second step of the subsequent process.



Pyrroles. Clarke and Lapworth⁴⁴⁸ have assumed that the pyrrole synthesis discovered by von Miller and Ploechl⁴⁴⁹ involves a Michael reaction; thus, one could formulate the synthesis of 1-(*p*-tolyl)-2,3-diphenylpyrrole from α -toluidinobenzyl cyanide and cinnamaldehyde in the presence of potassium hydroxide as follows. (Compare ref. 450.)



⁴⁴⁷ Berson and Brown, *J. Am. Chem. Soc.*, **77**, 444 (1955).

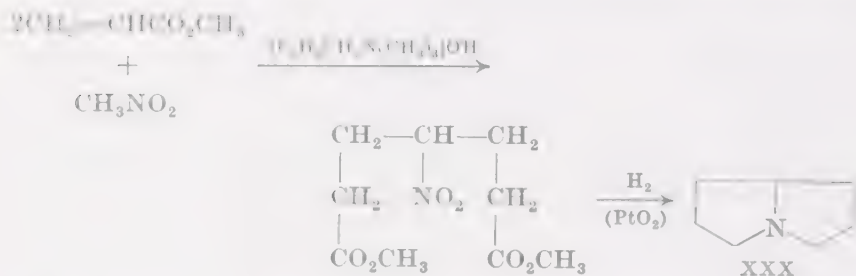
⁴⁴⁸ Clarke and Lapworth, *J. Chem. Soc.*, **91**, 694 (1907).

⁴⁴⁹ Miller and Ploechl, *Ber.*, **31**, 2718 (1898).

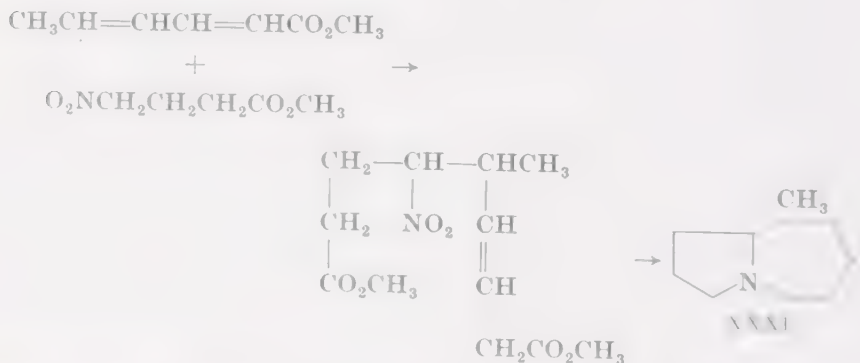
⁴⁵⁰ Bodforss, *Ber.*, **64**, 1111 (1931).

Treibs and Derra,⁴⁵¹ however, have suggested that the synthesis proceeds through a hemiacetal of the unsaturated aldehyde (formed by intermolecular addition with the solvent, e.g., methanol) and is, therefore, not a Michael reaction.

Pyrrolizidines and Related Ring Systems. The Michael condensation has been employed by Leonard in the preparation of pyrrolizidines (XXX) by reductive cyclization of γ -nitropimelic esters, which are available from nitroparaffins and acrylates or substituted acrylates.⁴⁵²⁻⁴⁵⁷



Similarly, the reaction has been extended to the synthesis of 6-methyl-azabicyclo[5.3.0]decane (XXXI) by 1,6-addition of methyl γ -nitrobutyrate to methyl sorbate, followed by reductive cyclization.¹¹⁶



There is also a synthesis of an indole derivative XXXII from quinone and ethyl iminoacetate (β -aminoacrylate),⁴⁵⁸ which can be formulated as follows.²⁵⁸

⁴⁵¹ Treibs and Derra, *Ann.*, **589**, 176 (1954).

⁴⁵² Leonard, Hruda, and Long, *J. Am. Chem. Soc.*, **69**, 690 (1947).

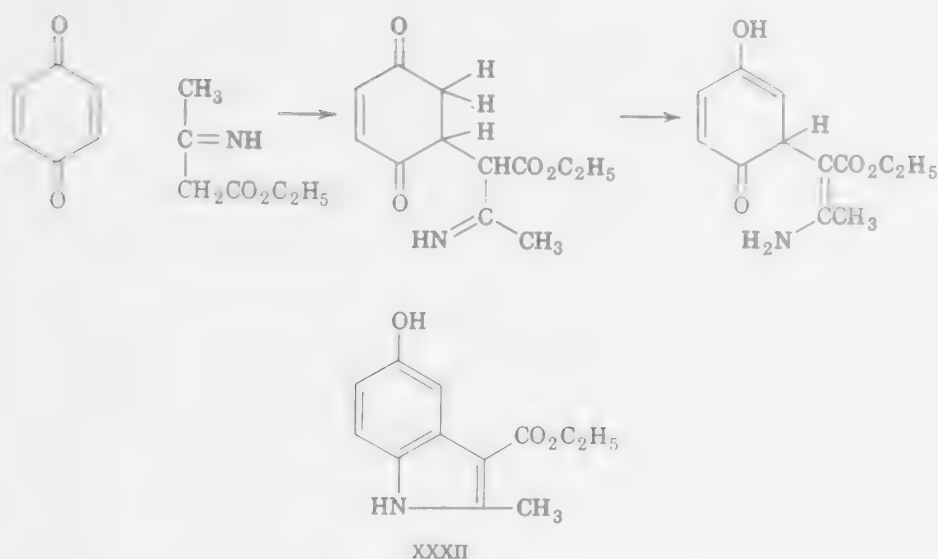
⁴⁵³ Leonard and Beck, *J. Am. Chem. Soc.*, **70**, 2504 (1948).

⁴⁵⁴ Leonard and Boyer, *J. Am. Chem. Soc.*, **72**, 4818 (1950).

⁴⁵⁵ Leonard and Shoemaker, *J. Am. Chem. Soc.*, **71**, 1762 (1949).

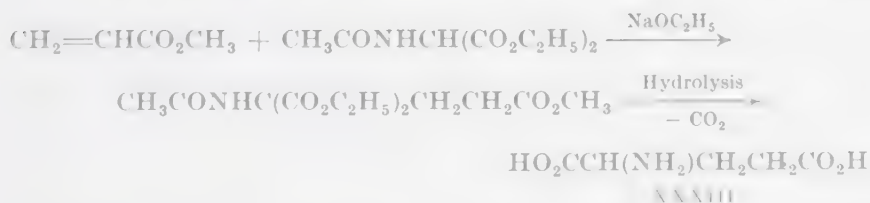
⁴⁵⁶ Leonard and Felley, *J. Am. Chem. Soc.*, **71**, 1758 (1949).

⁴⁵⁷ Leonard and Felley, *J. Am. Chem. Soc.*, **72**, 2537 (1950).



Synthesis of Amino Acids

The observation that substances such as ethyl acetamidomalonate and ethyl phthalimido-malonate or -cyanoacetate act as donors in the Michael condensation has opened a useful avenue to the synthesis of amino acids.^{161,458-462} The preparation of DL-glutamic acid (XXXIII) illustrates this method.⁴⁶³ The products derived from α,β -ethylenic aldehydes and N-acylated aminomalonates^{160,161,460-462,464} and aminocyanoacetates^{169,460} are likewise of considerable interest; they are potential



intermediates in the construction of the ornithine system and appear to be the key substances in the biogenesis of a number of alkaloids.⁴⁶⁵

⁴⁵⁸ Albertson and Archer, *J. Am. Chem. Soc.*, **67**, 2043 (1945).

⁴⁵⁹ Galat, *J. Am. Chem. Soc.*, **69**, 965 (1947).

⁴⁶⁰ Moe and Warner, *J. Am. Chem. Soc.*, **70**, 2763 (1948).

⁴⁶¹ Rinderknecht and Niemann, *J. Am. Chem. Soc.*, **72**, 2296 (1950).

⁴⁶² Van Zyl, van Tamelen, and Zuidema, *J. Am. Chem. Soc.*, **73**, 1765 (1951).

⁴⁶³ Snyder, Shekleton, and Lewis, *J. Am. Chem. Soc.*, **67**, 310 (1945).

⁴⁶⁴ Moe and Warner, U.S. pat. 2,508,927 [*C.A.*, **44**, 8374 (1950)].

⁴⁶⁵ Robinson, *Proc. Univ. Durham Phil. Soc.*, **8**, Pt. 1, 14 (1927-1928) [*C.A.*, **23**, 1883

As esters of nitroacetic acid become more generally available, these may also be used in the synthesis of amino acid precursors through the Michael condensation.^{106,466}

EXPERIMENTAL CONDITIONS

Solvents. If the products are sensitive to alcoholysis or if there is competition between the alkoxide ion and the donor anion for the acceptor molecule, a non-hydroxylic solvent is chosen or the reaction is carried out without solvent. Compare, however, ref. 278. When such competition is encountered or when the enolate of the donor is prepared with difficulty, sodium or sodium amide in an inert solvent may be used. Solvents used most often in the Michael condensation are methanol, ethanol, *t*-butyl alcohol, ether, benzene, dioxane, and mixtures of these solvents. Ester exchange has been observed in some condensations in which esters were employed as reactants.¹⁸³

Catalysts. The following catalysts have been used: sodium methoxide, sodium ethoxide, potassium methoxide, potassium ethoxide, potassium isopropoxide, potassium *n*-butoxide, potassium *t*-butoxide, potassium *z,z*-dimethylpropoxide; dry or aqueous sodium or potassium hydroxide, methanolic or ethanolic sodium or potassium hydroxide, potassium hydroxide in *t*-butanol, metallic sodium or potassium; ammonia, alcoholic ammonia, ammonia in conjunction with ammonium chloride, sodium amide as such or in liquid ammonia; diethylamine, diisopropylamine, piperidine, pyridine, triethylamine, tributylamine, and other trialkylamines; methyltriethylammonium hydroxide, benzyltrimethylammonium hydroxide (Triton B), and its methoxide or butoxide.

Calcium and sodium hydride have been used very rarely;^{186,466a,467} the same applies to potassium carbonate²⁰⁶ and sodium triphenylmethide,⁴⁶⁸ which was used as condensing agent for Michael reactions with the ethyl esters of acetic, isobutyric, and phenylacetic acids. The first ester underwent Claisen condensation under these conditions before Michael reaction took place.

Aqueous sodium cyanide was employed as catalyst in the condensations of acrylonitrile with ethyl cyanoacetate or benzyl cyanide.⁴⁶⁹

It is worthy of note that the reaction between cyclohexanone or 2-methyleyclohexanone and acrylonitrile, carried out in the presence of

⁴⁶⁶ E. D. Bergmann, unpublished results.

^{466a} Fishman and Zuffanti, *J. Am. Chem. Soc.*, **73**, 4466 (1951).

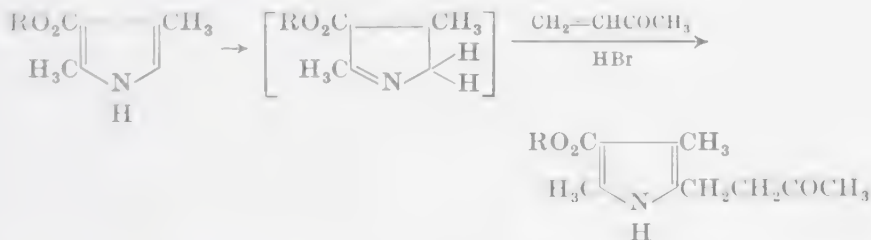
⁴⁶⁷ McElvain and Lyle, Jr., *J. Am. Chem. Soc.*, **72**, 384 (1950).

⁴⁶⁸ Hauser and Abramovitch, *J. Am. Chem. Soc.*, **62**, 1763 (1940).

⁴⁶⁹ Rogers, U.S. pat. 2,460,536 [*C.A.*, **43**, 3446 (1949)].

optically active quartz, coated with sodium, potassium, or lithium ethoxide, has been reported to give slightly optically active products.⁴⁷⁰

Several examples have been reported^{155,255,471-473} of Michael-type condensations brought about by acidic catalysts such as boron trifluoride, zinc chloride, or sulfur dioxide. Of practical importance are the condensations of pyrrole derivatives with free α positions which react with α,β -unsaturated aldehydes, ketones, acids, and acid derivatives in the presence of acidic catalysts such as boron trifluoride etherate or hydrobromic acid.^{474,475} As in the case of indole (see p. 209), one can assume that the donor is a tautomeric form of the pyrrole, in which the α position is transformed into an (activated) methylene group. This product reacts further to give a dipyrrolyltrimethine derivative.



One or two condensations have been effected without an added catalyst. Thus condensation occurs when ethyl hydroxymethylenepherylacetate is heated with malonic or cyanoacetic acid,^{366,476,477} and when methyl vinyl ketone vapor is passed together with acetone or methyl ethyl ketone through a hot tube.⁴⁷⁹

Particular mention should be made of the possibility offered by the recent development of strongly basic exchange resins; they appear to be highly promising condensing agents, especially where either a reactant or a reaction product is sensitive to dissolved alkali. Thus acetone or methyl ethyl ketone reacts easily with acrylonitrile in the presence of quaternized cross-linked polyvinylpyridine resin.⁴⁷⁸ More complicated reactions can also be catalyzed in this way.^{479,480}

⁴⁷⁰ Tarque, vs. Fikhtengolts, and Budovskii, *Sbornik Statei Obshchei Khim.*, **2**, 1612 (1953) [*C.A.*, **49**, 5263 (1955)].

⁴⁷¹ Hauser, *J. Am. Chem. Soc.*, **60**, 1957 (1938).

⁴⁷² Hauser and Breslow, *J. Am. Chem. Soc.*, **62**, 2389 (1940).

⁴⁷³ Berlin and Sherlin, *J. Gen. Chem. USSR*, **8**, 16 (1938) [*C.A.*, **32**, 5397 (1938)].

⁴⁷⁴ Treibs and Miel, *Ann.*, **589**, 163 (1954).

⁴⁷⁵ Treibs and Herrmann, *Ann.*, **592**, 1 (1955).

⁴⁷⁶ Phalnikar and Nargund, *J. Univ. Bombay*, **4**, 106 (1935) [*C.A.*, **30**, 5186 (1936)].

⁴⁷⁷ Harris, Stiller, and Folkers, *J. Am. Chem. Soc.*, **61**, 1242 (1939).

⁴⁷⁸ Hawk and Langkammerer, U.S. pat. 2,579,580 [*C.A.*, **46**, 7114 (1952)].

⁴⁷⁹ E. D. Bergmann and R. Korett, *J. Org. Chem.*, **21**, 107 (1956); **23**, 1507 (1958).

⁴⁸⁰ Schmide and Mansfield, U.S. pat. 2,658,070 [*C.A.*, **48**, 13715 (1954)].

Only qualitative conclusions can be drawn from the available experimental material regarding the catalysts used in the Michael reaction. One is inclined to assume that the efficiency of a particular catalyst in a given reaction is due to its ability to enolize the donor,⁴⁶⁸ but a few more factors are important in the selection of a condensing agent. Thus, piperidine seems to cause secondary cyclization reactions less easily than sodium ethoxide, but it also acts relatively slowly. These secondary reactions can also be avoided when less (1/6 to 1/3) than the equivalent amount of the ethoxide is employed or the reaction is carried out at low temperature.^{58,481} On the other hand, ethanolic solutions of potassium ethoxide are likely to cause ring scission of cyclopentanone or cyclohexanone derivatives.

Sometimes, when piperidine is not effective, reaction can be achieved by means of sodium ethoxide, e.g., the Michael condensation between ethyl cinnamate and ethyl phenylacetate. Dry potassium hydroxide or a mixture of pyridine and aqueous sodium hydroxide has been employed successfully with fluorene and its derivatives, substances in which the catalyst does not cause enolization but replacement of hydrogen on a carbon atom.^{362,482} The use of dry potassium hydroxide, however, is not limited to this particular group of donors. It has been shown that suspensions of finely divided potassium hydroxide in acetals (which perhaps form loose molecular compounds with the base) are excellent catalysts for Michael condensations.⁴⁸³ Surprisingly, ester groups are not attacked under these conditions, although the hydroxide usually employed contains about 15% water. It is interesting that only potassium and not sodium hydroxide can be used in this way as a catalyst, particularly in view of the occasional observations on differences in behavior of the two alkali hydroxides when used as catalysts in the Michael condensation.²⁰⁵ It has also been observed that 4-picoline condenses with 4-vinylpyridine to give 1,3-di-(4-pyridyl)propane in the presence of metallic potassium, but not under the influence of metallic sodium.⁴⁸⁴

Temperature. Higher temperatures usually favor rearrangement and retrogression (see p. 187) as well as secondary cyclization reactions, both of which, of course, reduce the yield of normal adduct. With alkoxide catalysts, reaction times of twenty to one hundred fifty hours at room temperature have been used with good results. When employing secondary amines as catalysts, it is usually necessary to reflux the mixture for twenty to forty-eight hours in order to obtain a fair yield of product.

⁴⁶¹ Wachs and Hedenburg, *J. Am. Chem. Soc.*, **70**, 2695 (1948).

⁴⁶² Kloetzel and Mertel, *J. Am. Chem. Soc.*, **72**, 4786 (1950).

⁴⁶³ Weizmann, Bergmann, and Sulzbacher, *J. Org. Chem.*, **15**, 918 (1950).

⁴⁶⁴ Jampolsky, Baum, Kaiser, Sternbach, and Goldberg, *J. Am. Chem. Soc.*, **74**, 5222 (1952).

EXPERIMENTAL PROCEDURES

γ -Acetamido- γ -carbethoxy- γ -cyanobutyraldehyde.⁴⁶⁰ A solution of 50 mg. of sodium in 100 ml. of absolute ethanol is mixed with 17 g. of ethyl acetamidocyanacetate, and the resulting suspension is cooled in a water bath while 7.5 ml. of acrolein is added dropwise. After the addition is complete, the mixture is stirred for two hours and neutralized with glacial acetic acid. The mixture is filtered, and the filtrate, after refrigeration for twenty-four hours, deposits the crystalline product. Filtration yields 15 g. (66%) of material melting at 106-109°. Crystallization from 95% ethanol raises the melting point to 113.5-114.5°.

5-Nitro-4,4-dimethylpentan-2-one.²⁰⁹ A mixture of 1 mole of mesityl oxide, 10 moles of nitromethane, and 1 mole of diethylamine is allowed to stand at 30° for thirty days. Unreacted material is removed by distillation up to 55°/20 mm., and the residue is fractionated. After a forerun of 4-diethylamino-4-methylpentan-2-one (10%), the product distills as an oil, b.p. 112-113.5°/14 mm. (65%). The product may be completely freed of basic impurities by shaking with 10% hydrochloric acid. After two distillations, a pure product, boiling at 128-129°/22 mm., can be obtained in 58% yield.

The same product may be obtained in 55-60% yield by heating the reaction mixture under reflux for forty-eight hours and treating subsequently as above.

7-Keto-1-methoxy-13-methyl-5,6,7,9,10,13-hexahydrophenanthrene (Robinson's modification).⁴¹⁸ While 15.05 g. of diethylaminobutanone⁴⁸⁰ is swirled gently in a 1-l. flask and cooled in ice, 15.0 g. of methyl iodide is added portionwise during thirty minutes. The swirling is regulated so as to obtain the crystalline methiodide as an even coating on the walls of the flask. When no more liquid remains, the flask is kept in ice for thirty minutes and then under the tap for forty-five minutes. A solution of 20.0 g. of 5-methoxy-1-methyl-2-tetralone in 100 ml. of dry thiophene free benzene is added, air is expelled by dry nitrogen, and a solution of 6.5 g. of potassium in 100 ml. of dry ethanol is added with cooling during five minutes.

Swirling is continued until the methiodide dissolves (about thirty minutes) and is replaced by a precipitate of potassium iodide. The mixture is kept in ice for an additional hour, and then boiled gently for twenty-five minutes. An excess of 2 *N* sulfuric acid is added, followed by enough water to dissolve the potassium sulfate. The benzene layer is separated and the aqueous layer extracted twice with ether. The ether and benzene layers are combined, washed with water, and clarified with

⁴⁶⁰ Wilds and Shunk, *J. Am. Chem. Soc.*, **65**, 469 (1943).

magnesium sulfate, and the solvents are evaporated. The residue is distilled and 23.2 g. of product is collected up to 180°/0.1 mm. Crystallization from ether yields 17 g. of product, m.p. 115–117°. An additional gram of material is obtained by distillation of the mother liquors, making a total yield of 18 g. (71%).

This procedure is a general one, in which sodium methoxide or sodium ethoxide may be used effectively as a catalyst.

***trans*-3-Keto-2-phenylcyclohexaneacetic Acid.**¹⁹⁸ A mixture of 50 g. of 2-phenyl-2-cyclohexen-1-one, 150 g. of dibenzyl malonate, and a solution of potassium *t*-butoxide, prepared from 1.3 g. of potassium and 20 ml. of *t*-butyl alcohol, is kept at 60° for three hours, and then left overnight at room temperature. The mixture is acidified with 2.5 ml. of acetic acid and diluted to a volume of 250 ml. with ethyl acetate. Thirteen grams of 10% palladium-charcoal is added, and the mixture is hydrogenated for an hour at room temperature at an initial pressure of 4 atm. The catalyst is filtered, the solvent evaporated, and the residue is heated for 10 minutes at 170–180° to effect decarboxylation of the malonic acid. The residue is taken up in ether, the solution extracted several times with 10% sodium carbonate solution, and the alkaline extract acidified. The product is obtained as a solid, m.p. 125° (55 g., 82%).

Dibenzyl malonate is preferred to diethyl malonate as a donor if further hydrolysis of the Michael condensation adduct is desired.

Methyl 3-Keto-2-phenylcyclohexyl- α -nitroacetate.^{106,108} A mixture of 17.2 g. of 2-phenyl-2-cyclohexen-1-one, 23.0 g. of methyl nitroacetate,⁴⁸⁶ and 0.025 mole of 30% methanolic solution of benzyltrimethylammonium methoxide⁴⁸⁷ is allowed to stand at 60° for twelve hours. The mixture is acidified with acetic acid and extracted with ether, and the extract is washed with water and with sodium bicarbonate solution to remove most of the unchanged ester. After removal of the rest of the unreacted materials by distillation in high vacuum, 26.2 g. of product (90% yield) is obtained as an oil.

Triethyl α -Acetyltricarballoylate.⁴⁸⁴ To 20 g. of technical potassium hydroxide in 150 ml. of acetaldehyde dipropyl acetal are added 51.6 g. of diethyl maleate and 52 g. of ethyl acetoacetate, the temperature being maintained at 20° during the addition. The temperature then rises spontaneously to 27°, and the mixture is heated at 90° for one hour. After acidification with dilute sulfuric acid, the acetal layer is separated, the solvent is removed, and the residue distilled in vacuum. Some ethyl acetoacetate is recovered, and 65 g. of product is obtained as an oil.

⁴⁸⁶ Feuer, Hass, and Warren, *J. Am. Chem. Soc.*, **71**, 3078 (1949).

⁴⁸⁷ Croxall and Schneider, *J. Am. Chem. Soc.*, **71**, 1257 (1949). Cf. Meisenheimer, *Ann.*, **397**, 295 (1913).

b.p. 180°/12 mm. The yield based on material that entered the reaction is 72%.

Diethyl 6-Keto-4-methyl-2-heptene-1,5-dicarboxylate.⁴⁸⁸ To a solution of 2.5 g. of potassium in 150 ml. of absolute *t*-butyl alcohol are added 98 g. of ethyl acetoacetate and 53 g. of ethyl sorbate. The mixture is heated under reflux in an oil bath at 110–120° for twelve hours. The cooled solution is poured into dilute sulfuric acid and the precipitated oil taken up in benzene. After removal of the benzene and unreacted material by distillation, 78 g. of product (75% yield) is obtained as an almost colorless oil, b.p. 120°/0.5 mm.

Hexaethyl 3-Butene-1,1,2,2,3,4-hexacarboxylate.^{324,325,489} Under anhydrous conditions and with stirring, a mixture of 34 g. of diethyl acetylenedicarboxylate, 66 g. of tetraethyl ethane-1,1,2,2-tetracarboxylate, and 10 ml. of absolute ethanol is heated to 45° to obtain a clear solution. A solution of 1.5 g. of sodium dissolved in 24 ml. of absolute ethanol is added dropwise with rapid stirring. After addition of about 10 drops of ethoxide solution, the temperature of the reaction mixture suddenly rises to 92° and then slowly falls as the rest of the catalyst is added. As the temperature rises, the color of the solution changes to dark brown. The mixture is poured into 100 ml. of *N* hydrochloric acid and is exhaustively extracted with ether. Evaporation of the ether leaves a mixture of solid and oil. The solid is collected and crystallized from 80% ethanol. The product, obtained in several crops, weighs 48.5 g. (48%) and melts at 78°.

Diethyl α,β -Diphenylglutarate.^{81,82} One hundred grams of ethyl cinnamate and 100 g. of ethyl phenylacetate are mixed with a solution of 4 g. of sodium in 60 ml. of ethanol and heated under reflux for two and one-half hours. The mixture is neutralized with the calculated amount of dilute hydrochloric acid, and enough water is added to produce turbidity. When the solution is cooled, the product crystallizes in quantitative yield as a mixture of isomers. After several crystallizations from dilute ethanol, the product melts at 92–93°.

Dimethyl (α -Phenyl- β -nitroethyl)malonate.³²⁹ To an ice-cold solution of 26 g. of dimethyl malonate and 1 g. of sodium in 30 ml. of dry methanol, 5 g. of finely powdered *o*-nitrostyrene is added. The mixture is shaken until all the solid dissolves. The clear solution is acidified with glacial acetic acid, cooled in ice, and saturated with hydrogen chloride. When the solution is colorless, it is poured into a suspension of ice in sodium carbonate. The colorless oil that precipitates crystallizes upon scratching. The product is washed with water and crystallized from methanol to furnish 8.7 g. (92%) of the ester, m.p. 57°.

⁴⁸⁸ Ames and Bowman, *J. Chem. Soc.*, **1950**, 329.

⁴⁸⁹ Reid and Sack, *J. Am. Chem. Soc.*, **73**, 1985 (1951).

Ethyl α -Benzoyl- γ -(2-pyridyl)butyrate.⁴⁹⁰ To a mixture of 246 g. of freshly distilled ethyl benzoylacetate and 66 g. of freshly distilled 2-vinylpyridine, 1 g. of sodium is added, and the mixture is boiled for five hours. The solution is cooled, acidified, and extracted with ether to remove neutral material. The aqueous layer is made alkaline, the oil that separates is taken up in ether, and the extract is dried over anhydrous calcium sulfate. The ether and 2-vinylpyridine are evaporated under reduced pressure, and the residue is distilled to furnish 135 g. (79%) of the product as a pale orange oil, b.p. 170–175°/0.3 mm.

TABULAR SURVEY OF THE MICHAEL CONDENSATIONS

The following tables summarize the data in the literature through October 1955. Tables I–XXI classify the material according to the unsaturated acceptors. Table XXII lists most of the important donors that have been used in the Michael condensation.

The acceptors in Tables I–XXI have been arranged according to increasing number of carbon atoms unless otherwise stated. Alkyl esters are listed (independent of the number of the carbon atoms in the alkyl group) under the lowest member of the series employed. With each acceptor, the donors have been listed according to the following scheme:

- Esters and other acid derivatives (except nitriles)
- Keto esters
- Cyano compounds
- Aldehydes and ketones
- Nitro compounds
- Sulfones
- Miscellaneous donors

Commas between items in the catalyst column separate the components of a catalyst combination; semicolons are used to separate different catalyst combinations.

When yields are cited, the first references cited are those to the articles containing the information on yields.

⁴⁹⁰ Boekelheide and Agnello, *J. Am. Chem. Soc.*, **72**, 5005 (1950).

TABLE I

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC ALDEHYDES

Reactants	Catalyst	Product (Yield, %)	References
Acrolein and Diethyl malonate	NaOC_2H_5 ($n\text{-C}_4\text{H}_9$) ₃ N	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (50)	159, 417, 491
Diethyl ethylmalonate	NaOC_2H_5	$\text{A}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$	492
Diethyl α -cyanoethylmalonate	NaOC_2H_5	$\text{AC}(\text{C}_2\text{H}_5)_n(\text{CO}_2\text{C}_2\text{H}_5)_2$ (40)	159, 161, 491
Diethyl α -deoxymalonnate	NaOC_2H_5	$\text{AC}(\text{C}_6\text{H}_{13-n})_n(\text{CO}_2\text{C}_2\text{H}_5)_2$	159, 161, 491
Diethyl α -deoxyimidonate	NaOC_2H_5	$\text{AC}(\text{C}_{10}\text{H}_{21-n})_n(\text{CO}_2\text{C}_2\text{H}_5)_2$	159, 161, 491
Diethyl bromomalonate	$(m\text{-C}_4\text{H}_9)_3\text{N}$; NaOC_2H_5	$\text{AC}(\text{C}_{16}\text{H}_{33-n})_n(\text{CO}_2\text{C}_2\text{H}_5)_2$	491
Diethyl chloromalonate	$(m\text{-C}_4\text{H}_9)_3\text{N}$	$\text{ACBr}(\text{CO}_2\text{C}_2\text{H}_5)_2^*$	159, 493
Diethyl formamidomalonate	NaOC_2H_5	$\text{AC}(\text{NHCCH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$	494
Diethyl acetamidomalonate	Na	$\text{AC}(\text{NHCCH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$	460
	NaOCH_3	$\text{AC}(\text{NHCOCH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (87)	461
	NaOC_2H_5	$\text{AC}(\text{NHCOCH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (61)	462, 494, 495
	Exchange resin (HO- or CN-form)	$\text{AC}(\text{NHCOCH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (56)	496
		$\text{AC}(\text{NHCOCH}_3)\text{CO}_2\text{C}_2\text{H}_5)_2$ (62) [†]	
Diethyl phthalimidomalonate	NaOC_2H_5	$ \begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{C} \\ \diagdown \quad \diagup \\ o\text{-C}_6\text{H}_4 \quad \text{N}(\text{CO}_2\text{C}_2\text{H}_5)_2 \\ \\ \text{C}' \\ \\ \text{O} \quad \text{A} \end{array} $	460, 494

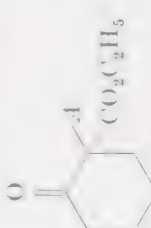

Note: References 491-1045 are on pp. 545-555.



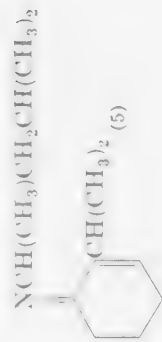
* When sodium ethoxide was used as the catalyst, dehydrhalogenation took place.

† The product was isolated as the phenylhydrazone.

TABLE I—Continued

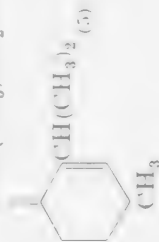
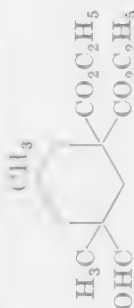
MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC ALDEHYDES

Reactants	Catalyst	Product (Yield, %)	References
<i>Acrolein (Cont.) and</i>			
Diethyl acetoxy malonate	NaOC_2H_5 NaOC_2H_5	$\text{CH}_3\text{CO}_2\text{C}(A)(\text{CO}_2\text{C}_2\text{H}_5)_2$ $A_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$; 5,5-diacethoxy-1-cyclohexene-1-carboxaldehyde	159, 497 110, 417
$\text{CH}_2\text{CH}_2\text{CHO}$	NaOC_2H_5	$\text{CH}_3\text{C}(\text{OCH}(A)\text{CO}_2\text{C}_2\text{H}_5)(40, 39)$; 2-cyclohexen-1-one (20, 23)	498, 499
Ethyl acetoacetate	NaOC_2H_5 Not indicated NaOC_2H_5	$\text{CH}_3\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ 2-Cyclohexen-1-one 6-Methyl-2-cyclohexen-1-one (20)	500 501 499
Ethyl methylacetoacetate			
Ethyl cyclohexanone-2-carboxylate	NaOC_2H_5		162
Ethyl cyanoacetate	NaOC_2H_5	$\text{A}(\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5)(12)$; 5-carbethoxy-5-cyano-1-cyclohexene-1-carboxaldehyde	159, 417, 502, 503
Ethyl acetamidocyanoacetate	NaOC_2H_5 NaOC_2H_5	$\text{AC}(\text{NHCOCH}_3)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (82, 60) $A_2\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (18)	460, 494, 504 110, 417
$\text{CH}_2\text{CH}_2\text{CHO}$			
Cyclohexanone-2-carboxaldehyde	SO_2	$A-\text{CHO}$  (23)	472

3-Cyclohexene-1-carboxaldehyde	SO ₂		472
Diethylacetylenetriamine	NaOC ₂ H ₅	$C_6H_5CH(A)COC_6H_5$ (100)	163
Acetylacetone	Pyridine	$(CH_3)(OC_6H_4A)COC_6H_5$ (27); 6-Acetyl-2-cyclohexenyl-one (13); compound $C_{13}H_{18}O_4$ (27);	505
			
Nitromethane	$[C_6H_5CH_2N(CH_3)_3]OH$; NaOCH ₃	ACH_2NO_2 (41)	506
Nitroethane	$[C_6H_5CH_2N(CH_3)_3]OH$; NaOCH ₃	$CH_3CH(A)NO_2$ (51)	506
1-Nitropropane	NaOC ₂ H ₅	$CH_3CH_2CH(A)NO_2$ (30)	507
2-Nitropropane	$[C_6H_5CH_2N(CH_3)_3]OH$; NaOCH ₃	$(CH_3)_2C(A)NO_2$ (49)	506
	NaOC ₂ H ₅	$(CH_3)_2C(A)NO_2$ (33)	506
	K ₂ CO ₃	$(CH_3)_2C(A)NO_2$	507
Ethyl nitroacetate	NaOC ₂ H ₅	$(CH_3)_2C(A)NO_2$ (35)	508
Diethyl nitromalonate	NaOC ₂ H ₅	$ACH(NO_2)CO_2C_2H_5$	509
	Exchange resin (HO- or CN-form)	$AC(NO_2)CO_2C_2H_5$ (94)	510
		$AC(NO_2)CO_2C_2H_5$ (94)	496
$(CH_3)_2CHCH_2C(CH_3)=NCH(CH_3)CH_2CH(CH_3)_2$	None		375

Note: References 491-1045 are on pp. 545-555.

Diethyl chloromalonate	$(\text{C}_2\text{H}_5)_2\text{N}$	493
Diethyl acetamidomalonate	NaOC_2H_5	160, 494
Diethyl acetoxyimaleonate	NaOC_2H_5	497
Ethyl acetacetate	Not indicated	498
	NaOC_2H_5	499
$(\text{CH}_3)_2\text{CHCH}_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$		
CHO		110
Ethyl cyanoacetate	NaOC_2H_5	503
Ethyl acetamidocyanoacetate	NaOC_2H_5	160, 494
β -Methoxycyclobutylaldehyde	NaOH	513
β -Ethoxycyclobutylaldehyde	NaOH	513
β -Allyloxycyclobutylaldehyde	NaOH	513
β -n-Butoxycyclobutylaldehyde	NaOH	513
1-Nitropropane	NaOC_2H_5	507
2-Nitropropane	NaOC_2H_5	507
Ethyl nitroacetate	K_2CO_3	503
Ethyl nitromalonate	NaOC_2H_5	509
	NaOC_2H_5	510
$(\text{CH}_3)_2\text{CHCH}_2\text{C}(\text{CH}_3)=$ $\text{NCH}(\text{CH}_3)\text{CH}_2\text{CH}(\text{CH}_3)_2$	None	375



Note: References 491–1045 are on pp. 545–555.

- * When sodium ethoxide was used as the catalyst, dehydrohalogenation took place.
- † The alkoxy aldehyde was formed in situ from methacrolein and the appropriate alcohol.
- ‡ The position of the nuclear double bond has not been established.

TABLE I—Continued
MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC ALDEHYDES

Reactants	Catalyst	Product (Yield, %)	References
β -Hydroxycrotonaldehyde and $\text{H}_2\text{N}(\text{C}(\equiv\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)_2$	None	Ethyl 2-amino-6-methylpyridine-3-carboxylate (13)	514
β,β -Dimethylacrolein and β -Ethoxyacrolein ∇ and $\text{H}_2\text{N}(\text{C}(\equiv\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)_2$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{CN}$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{COC}_6\text{H}_5$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{COC}_6\text{H}_5$	NaNH_2	4,6,6-Trimethyl-1,3-cyclohexadiene-4-carboxaldehyde Ethyl 2-aminopyridine-3-carboxylate (18) Ethyl 2-methylpyridine-3-carboxylate (30) 3-Cyano-2-methylpyridine (4) 3-Acetyl-2-methylpyridine (25) 3-Benzoyl-2-methylpyridine (5)	516 514 515 515 515 515
β -Ethoxycrotonaldehyde ∇ and $\text{H}_2\text{N}(\text{C}(\equiv\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)_2$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{CN}$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{COC}_6\text{H}_5$ $\text{CH}_3\text{C}(\equiv\text{NH})\text{CH}_2\text{COC}_6\text{H}_5$	None None None None None	Ethyl 2-amino-6-methylpyridine-3-carboxylate Ethyl 2,6-dimethylpyridine-3-carboxylate (40) 3-Cyano-2,6-dimethylpyridine (40) 3-Acetyl-2,6-dimethylpyridine (40) 3-Benzoyl-2,6-dimethylpyridine (35)	514 166 166 166 166
α -Methyl- β -ethylacrolein and β -Ethoxycrotonaldehyde	KOCH_3 , aq. NaOH , 130–180°	$\text{CH}_3\text{CH}_2\text{CHCH}(\text{CH}_3)\text{C}=\text{O}$ (42, 15)	165, 164
Diethylbenzoin	NaOCH_3	$\begin{array}{c} (\text{CH}_3)_2\text{C}=\text{CH}_2-\text{O} \\ \\ \text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}(\text{CH}_3)\text{CHO} \\ \\ \text{C}_6\text{H}_5\text{CHCOC}_6\text{H}_5 \end{array}$	163

α-Ethyl-β-n-propylacrolein and

Ethyl acetoacetate

KOH, acetal



483, 517, 518

Butyraldehyde**

Aq. NaOH, 200°



164

*Cinnamaldehyde and*

Diethyl ethylmalonate

NaOCH₃

519

Diethyl acetamidomalonic

NaOC₂H₅

464

Ethyl acetoacetate

NaOC₂H₅

6-Carboethoxy-5-phenyl-2-cyclohexen-1-one

512

Ethyl *n*-butylcyanoacetateNaOCH₃

519

Ethyl formamidoxyanoacetate

NaOC₂H₅

464

Phenylacet aldehyde

NaOCH₃

163

Deoxybenzoin

NaOCH₃

163

1-Nitropropane

NaOC₂H₅

520

2-Nitropropane

NaOC₂H₅

520

β-Hydroxycinnamaldehyde and

None

Ethyl 2-amino-6-phenylpyridine-3-carboxylate (31)

521

2-Heptylideneheptanal†† and

Heptanal

Aq. NaOH, 200°

3-*n*-Hexyl-2,4-di-*n*-pentylvalerolactone (9)

167

Note: References 491–1045 are on pp. 545–555.

Malonic acid ethyl ester imino ether was employed; it reacted as the amidine.

¶ The aldehyde was introduced in the form of its acetal.

** The butyraldehyde was formed *in situ* by scission of *α*-ethyl-β-*n*-propylacrolein.†† The unsaturated aldehyde was formed *in situ* from heptanal.

Not indicated	 A cyclohexene ring with a ketone group at position 2, a methyl group at position 4, and a carboxylate group at position 1. The carboxylate group is labeled $\text{CO}_2\text{C}_2\text{H}_5$.	529
$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 A cyclohexene ring with a ketone group at position 2, a methyl group at position 4, and a carboxylate group at position 1. The carboxylate group is labeled $\text{CO}_2\text{C}_2\text{H}_5$.	530
Ethyl 4-methyl-2-oxo-3-cyclohexene-1-carboxylate	NaOCH_3 A cyclohexene ring with a ketone group at position 2, a methyl group at position 4, and a carboxylate group at position 1. The carboxylate group is labeled $\text{CO}_2\text{C}_2\text{H}_5$.	122
Ethyl benzoylacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ A cyclohexene ring with a ketone group at position 2, a methyl group at position 4, and a carboxylate group at position 1. The carboxylate group is labeled $\text{CO}_2\text{C}_2\text{H}_5$.	536
Ethyl (x-furoyl)acetate	Not indicated A cyclohexanone ring with a carboxylate group at position 4, a hydroxyl group at position 3, and a furfuryl group at position 3. The carboxylate group is labeled $\text{CO}_2\text{C}_2\text{H}_5$.	531

Note: References 491-1045 are on pp. 545-555.

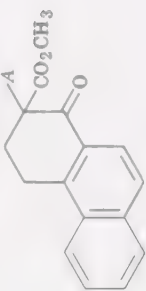
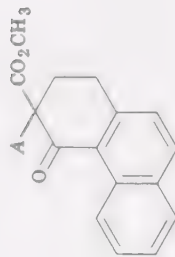
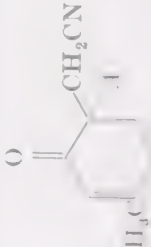
* In this condensation the amount of catalyst was twice that used in the preceding condensation.

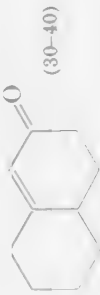
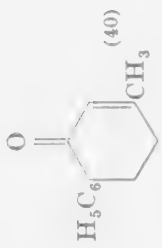
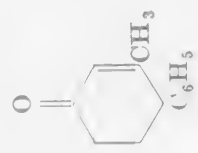
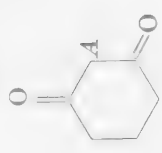
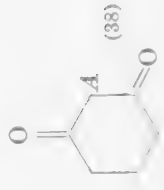
† Methyl chloroethyl ketone was employed.

‡ In this experiment the actual reagents used were the ester, acetone, and formaldehyde.

*** When the adduct was hydrolyzed, a 26% over-all yield of (±)-piperitone was obtained.

TABLE II—Continued

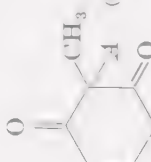
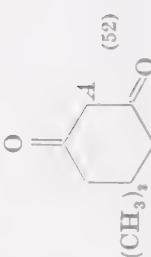
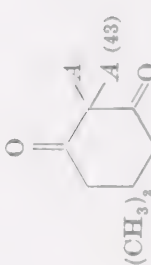

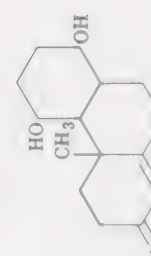
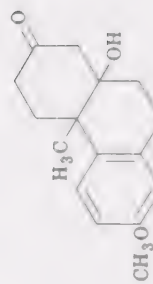
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES			
Reactants	Catalyst	Product (Yield, %)	References
<i>Methyl Vinyl Ketone (Cont.) and</i>			
Methyl 1-oxo-1,2,3,4-tetrahydro- phenanthrene-2-carboxylate	NaOCH ₃	$A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	532
			
Methyl 4-oxo-1,2,3,4-tetrahydro- phenanthrene-3-carboxylate	NaOCH ₃		533
		(89)	
Ethyl phenylpyruvate	Not indicated	3-(Carbethoxy-3-hydroxy-2-methyl-4-phenyl- cyclohexanone	531
		(A) ₂ C(CN) ₂ (74)	119, 122
		C ₆ H ₅ CH(A)CN	121
		C ₆ H ₅ C(A)(CN)CO ₂ C ₂ H ₅ (90)	121
Methyl 2-cyanoethyl ketone	KCN		123


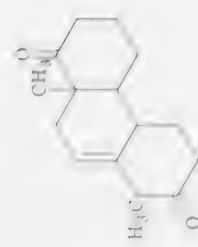
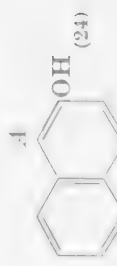
Acetone	—§	3-Methyl-2-cyclohexen-1-one (3)	419
Isobutyraldehyde	KOCH ₃	4,4-Dimethyl-2-cyclohexen-1-one (40)	534
Methyl ethyl ketone	—§	3,6-Dimethyl-2-cyclohexen-1-one (3)	419
Diethylacetaldehyde	KOCH ₃	4,4-Diethyl-2-cyclohexen-1-one	534
2-Ethylhexanal	KOCH ₃	4- <i>n</i> -Butyl-4-ethyl-2-cyclohexen-1-one	534
Cyclohexanone	Enamine from cyclohexanone	 (30-40)	535, 531
Phenylacetone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 (40) and 	536
Cyclohexane-1,3-dione	NaOCH ₃		532
	KOH, CH ₃ OH		538

Note: References 491–1045 are on pp. 545–555.

§ This experiment was run in the vapor phase, in the presence of oxides of group II to IV of the periodic system. This was reported as the probable structure of the product.


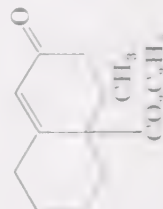
TABLE II—Continued

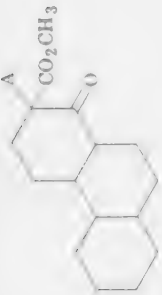
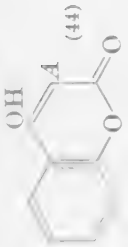
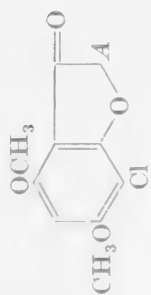
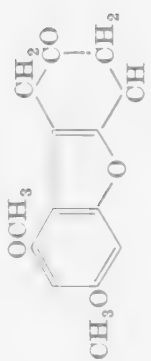
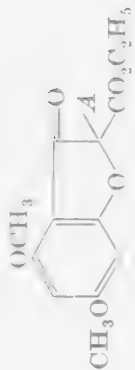
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES			
Reactants	Catalyst	Product (Yield, %)	References
<i>Methyl Vinyl Ketone (Cont.) and</i>		$A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	
2-Methylcyclohexane-1,3-dione	NaOCH_3 ; $(\text{C}_2\text{H}_5)_3\text{N}$	 (64)	525, 539
5,5-Dimethylcyclohexane-1,3-dione	KOH , CH_3OH	 (52)	538
5-Methyloctahydronaphthalene-1,6-dione	NaOCH_3	 (43)	115
	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 (39)	540, 541
6-Methoxy-1-methyl-2-tetralone	Not indicated		531

3-Hydroxymethylbenzofuran-4-keto-1,2,3,4-tetrahydronaphthene		533
	and the 3-formyl derivative	
	NaOC_2H_5 ; <i>t</i> -amines	542
Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$; $\text{A}\text{CH}_2\text{NO}_2$ (51)	506, 523
Nitroethane	NaOCH_3	506
2-Nitropropane	NaOCH_3	506, 543
Methyl fluorene-9-carboxylate	KOH	544
2-Naphthol	KOC_2H_5	168
		

Note: References 491-1045 are on pp. 545-555.

TABLE II—Continued

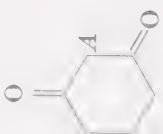
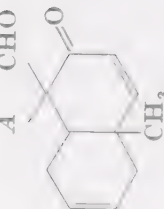

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES			References
Reactants	Catalyst	Product (Yield, %)	
<i>Methyl Vinyl Ketone (Cont.) and</i>		$A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	
Diethyl 3-hydroxybenzofuran-2-carboxylate	NaOC_2H_5		119
2'-Hydroxymethylene-1'-oxo-1',2',3',4'-tetrahydro-1,2-benz-3,4-aceperinaphthane	NaOCH_3	1'-Oxo-2'-(γ -oxobutyl)-1',2',3',4'-tetrahydro-1,2-benz-3,4-aceperinaphthane (70)	545
<i>Hydroxymethyleneacetone and</i>	KOC_4H_9	1'-Oxo-2'-(γ -oxobutyl)-1',2',3',4'-tetrahydro-1,2-benz-3,4-aceperinaphthane (26)	545
Ethyl acetoacetate	NaOC_2H_5	2-Hydroxy-4-methylbenzoic acid (55)	427
Diethyl acetone 1,3-dicarboxylate	NaOC_2H_5	Diethyl 2-hydroxy-4-methylisophthalate (49)	427
Nitronalate	$\text{CH}_3\text{COCH}=\text{CHONa}$	$\text{CH}_3\text{COCH}_2\text{CHOHCH}_2\text{NO}_2$ (4)	546
Ethyl malonate ^a	None	Ethyl 2-amino-6-methylnicotinate (32)	521
^a Acetoacetaldehyde	Piperidine acetate	3-Cyano-2-hydroxy-6-methylpyridine (55-62)	547
<i>Ethylideneacetone and</i>		$A = \text{CH}_3\text{CHCH}_2\text{COCH}_3$	
Diethyl methylmalonate	NaOC_2H_5	2,3-Dimethylcyclohexane-1,5-dione (10)	422
Ethyl 2-oxocyclohexane-1-carboxylate	KOC_2H_5		409

Methyl 4-oxo-4,2,3,4-tetrahydro- phthalidylidene-2-carboxylate	NaOC_2H_5		548
4-Hydroxycoumarin	Pyridine		169
7,4-Di-4,6-dimethoxycoumaran- 3-one	NaOC_2H_5		88
4,6-Dimethoxycoumaran-3-one	NaOC_2H_5		88
2-Carboethoxy-4,6-dimethoxy- coumaran-3-one	NaOC_2H_5		88

Note: References 491-1045 are on pp. 545-555.

* The ester imino ether was used.

TABLE II—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES					
Reactants	Catalyst	Product (Yield, %)	References		
<i>Ethyl Vinyl Ketone and</i>					
Diethyl malonate**	NaOC ₂ H ₅	$A = \text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_2-$	549		
Ethyl acetoacetate**	NaOC ₂ H ₅	ACh(CO ₂ C ₂ H ₅) ₂	550		
Acetylacetone**	NaOC ₂ H ₅	CH ₃ COCH(A)CO ₂ C ₂ H ₅ CH ₃ COCH(A)COCH ₃	549		
Cyclohexene-1,3-dione	Piperidine		537		
	KOC ₄ H ₉ - <i>l</i>	(45-57)	551		
<i>Divinyl Ketone and</i>					
# Methylcyclohexene-1,3-dione	NaOCH ₃		538		



Methyl Isopropenyl Ketone and

Ethyl acetoacetate

Na

420

Ethyl propionylacetate

Na

420

Ethyl isobutyrylacetate

KOH, $\text{C}_2\text{H}_5\text{OH}$ $(\text{CH}_3)_2\text{CHCOCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (75)

119

Acetone

KOH, CH_3OH

3,6-Dimethyl-2-cyclohexen-1-one (20)

418, 552††

Methyl ethyl ketone

KOH, CH_3OH

3,4,6-Trimethyl-2-cyclohexen-1-one†† (49, 43)

418, 552

Cyclohexanone

KOH, $\text{C}_2\text{H}_5\text{OH}$

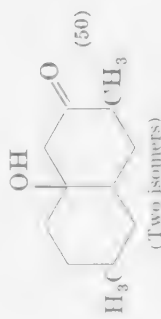
369, 101



4-Methylcyclohexanone

KOH, $\text{C}_2\text{H}_5\text{OH}$

101, cf. 8



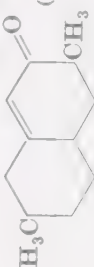
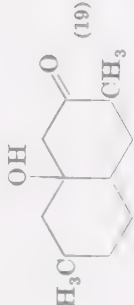
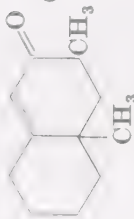
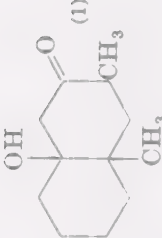
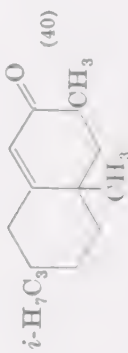
Note: References 491–1045 are on pp. 545–555.

** β -Chloroethyl ethyl ketone was employed.

†† When 3-hydroxy-3-methylbutan-2-one was used, instead of the unsaturated ketone, the yield was 11%.

‡‡ The same product was obtained from methyl ethyl ketone and formaldehyde (49–52%) and from methyl ethyl ketone and 3-hydroxy-3-methylbutan-2-one (43–49%).

TABLE II—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES			References
Reactants	Catalyst	Product (Yield, %)	
<i>Methyl Isopropenyl Ketone (Cont.) and</i>			
3 Methylcyclohexanone	KOH, C_2H_5OH	$4 \text{ } (CH_3(OCH(CH_3)CH_2 -$   (Two isomers)	101
2 Methylcyclohexanone	KOH, C_2H_5OH	  (1)	101
Tetrahydroarvone	KOH, C_2H_5OH	 (40)	101
<i>4-Hydroxy-3-penten-2-one and</i>			
Diethyl acetone-1,3-dicarboxylate	$NaOC_2H_5$	Diethyl 2-hydroxy-4,6-dimethylisophthalate (92)	427
Malonamide	None	4,6-Dimethyl-2-pyridone-3-carboxamide	370
Malonitrile	None	4,6-Dimethyl-3-cyano-2-pyridone	370

$\text{H}_2\text{N}(\text{C}=\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$	None	Ethyl 2-amino-4,6-dimethylpyridine-3-carboxylate (50, 69)	514, 521
Cyanoacetamide	None	4,6-Dimethyl-2-pyridone-3-carboxamide	370
Cyanoacetamide §§	Piperidine	3-Cyano-4,6-dimethyl-2-pyridone (87, 100)	553, 371, 554
$\text{NCCH}_2\text{CONHC}_2\text{H}_5$ §§	NH_3	3-Cyano-4,6-dimethyl-2-pyridone	555
$\text{NCCH}_2\text{CONHC}_2\text{H}_5$ §§	CH_3NH_2	3-Cyano-1,4,6-trimethyl-2-pyridone	555
$\text{NCCH}_2\text{CONHC}_2\text{H}_5$ §§	$\text{C}_2\text{H}_5\text{NH}_2$	3-Cyano-4,6-dimethyl-1-ethyl-2-pyridone	555
$\text{NCCH}_2\text{CONHC}_2\text{H}_5$ §§	$\text{CH}_2=\text{CHCH}_2\text{NH}_2$	1-Allyl-3-cyano-4,6-dimethyl-2-pyridone	555
$\text{CH}_3\text{COCH}_2\text{C}(=\text{NH})\text{CH}_3$ §§	None	Methyl 2,4,6-trimethyl-3-pyridyl ketone (> 75)	444
4-Amino-3-penten-2-one and			
Ethyl cyanoacetate	None	3-Cyano-4,6-dimethyl-2-pyridone	555
N-Methylcyanoacetamide	None	3-Cyano-1,4,6-trimethyl-2-pyridone	556
<i>Methyl α-Hydroxymethyleneethyl Ketone and</i>			
Cyanoacetamide	Piperidine	3-Cyano-4-hydroxy-5,6-dimethyl-2,3,4,5-tetrahydro-2-pyridone or 3-cyano-5,6-dimethyl-2-hydroxypyridine (23)	171, 172
$\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$	None	Ethyl 2,5,6-trimethylpyridine-3-carboxylate	557
3-Hydroxymethylenepentane-2,4-dione and			
Cyanoacetamide	NaOC_2H_5	Compound $\text{C}_9\text{H}_8\text{N}_2\text{O}_2$	254
<i>Mesityl Oxide and</i>		$\text{A} = \text{CH}_3\text{COCH}_2\text{C}(\text{CH}_3)_2$	
Dimethyl malonate	NaOCH_3	4-Carbomethoxy-5,5-dimethylcyclohexane-1,3-dione (85)	558

Note: References 491–1045 are on pp. 545–555.

¶ The ester imino ether was used.

§§ A mixture of ethyl cyanoacetate and ammonia or the appropriate amine was used in these experiments.

TABLE II—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES			
Reactants	Catalyst	Product (Yield, %)	References
<i>Mesityl Oxide (Cont.) and</i>		$A = \text{CH}_3\text{COCH}_2\text{C}(\text{CH}_3)_2$	
Diethyl malonate	NaOC_2H_5	5,5-Dimethylcyclohexane-1,3-dione (67-85) or 4-carbethoxy-5,5-dimethylcyclohexane-1,3-dione (95-97)	558, 558a
Diethyl methylmalonate	NaOC_2H_5	4,5,5-Trimethylcyclohexane-1,3-dione	315
Ethyl phenylacetate	NaOC_2H_5	5,5-Dimethyl-4-phenylcyclohexane-1,3-dione	82
Ethyl acetoacetate	NaOC_2H_5	3,5,5-Trimethyl-2-cyclohexen-1-one (low)	15, 16, 17, cf. 119
Ethyl benzoylacetate	NaOC_2H_5	4-Carbethoxy-5,5-dimethyl-3-phenyl-2-cyclohexen-1-one (44)	414
Methyl cyanoacetate	Na	$\text{NCCH}(\text{A})\text{C}(\text{O})_2\text{C}_6\text{H}_5$	415
Ethyl cyanoacetate	NaOC_2H_5	4-Cyano-5,5-dimethylcyclohexane-1,3-dione (50)	415, 425
Cyanoacetamide	NaOC_2H_5	3-Cyano-6-hydroxy-4,4,6-trimethyl-2-piperidone (quant.)	559
Deoxybenzoin	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{C}_6\text{H}_5$ and 5,5-dimethyl-3,4-diphenyl-2-cyclohexen-1-one	414
Acetylacetone	Na	6-Acetyl-3,5,5-trimethyl-2-cyclohexen-1-one	415
Nitromethane	NaOC_2H_5	ACH_2NO_2 (63)	560
Fluorene	$(\text{C}_2\text{H}_5)_2\text{NH}$	ACH_2NO_2 (65)	209
4-Hydroxycoumarin	KOH, pyridine	5-(9-Fluorenyl)-4,4-dimethylpentan-2-one (15-20)	561
	Pyridine	4-(4-Hydroxycoumarinyl)-4-methylpentan-2-one (13)	169
3-Ethyl-3-buten-2-one and			
Methyl propyl ketone	KOH, CH_3OH	4,6-Diethyl-3-methyl-2-cyclohexenone ¶¶ (7, 20)	552, 418

3-Methyl-3-penten-2-one and Dimethyl malonate	NaOC ₂ H ₅	4,5-Dimethylcyclohexane-1,3-dione*** (10)	422
2-Methyl-1-penten-3-one and Ethyl propionylacetate Ethyl methylacetate Ethyl ethylacetate	Not indicated Not indicated Not indicated	2,4-Dimethyl-3-ethyl-2-cyclohexenone 3-Ethyl-4,6-dimethyl-2-cyclohexenone 3,6-Diethyl-4-methyl-2-cyclohexenone	420 420 420
4-Hydroxy-3-methyl-3-penten-2-one and Cyanoacetamide §§ NCCH ₂ CONHCH ₃ §§	None Piperidine None	3-Cyano-4,5,6-trimethyl-2-pyridone 3-Cyano-4,5,6-trimethyl-2-pyridone 3-Cyano-1,4,5,6-tetramethyl-2-pyridone	555 562, cf. 563 555
Ethyl α-Hydroxymethyleneethyl Ketone and Cyanoacetamide CH ₃ C(=NH)CH ₂ CO ₂ C ₂ H ₅	sec-Amine None	3-Cyano-6-ethyl-2-hydroxy-5-methylpyridine Ethyl 6-ethyl-2,5-dimethylpyridine-3-carboxylate (50)	254 442
CH ₃ CH=NHCH ₂ CO ⁺ CH ₃ Nitromethane	None CH ₃ CH ₂ COC- (=CHONa)CH ₃	Methyl 6-ethyl-2,5-dimethyl-3-pyridyl ketone (46) 5-Hydroxy-4-methyl-6-nitrohexan-3-one (51)	442 546
Methyl β-Ethoxyvinyl Ketone and Cyanoacetamide	Piperidine	3-Cyano-6-methyl-2-pyridone (75)	564

Note: References 491-1045 are on pp. 545-555.

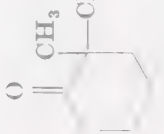
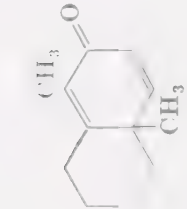
§§ A mixture of ethyl cyanoacetate and ammonia or the appropriate amine was used in these experiments.

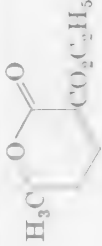
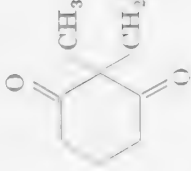
||| A mixture of trioxymethylene and the ketone was used.

*** The same product was obtained in 23% yield from the ketone and 3-ethyl-4-hydroxy-2-butanone, and in 20% yield from methyl propyl ketone and formaldehyde.

*** The name used in the reference is erroneous.

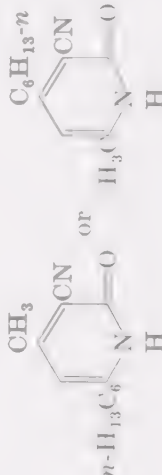
TABLE II—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES				
Reactants	Catalyst	Product (Yield, %)		References
<i>β-Methoxyvinyl Ethyl Ketone and</i>				
2-Methylcyclohexanone	Na		 (Small)	389
3-Hepten-2-one and Diethyl malonate	NaOC_2H_5	5-n-Propylcyclohexane-1,3-dione (16, 24)		565, 422
4-Methyl-3-hexen-2-one and Cyanoacetamide	NaOC_2H_5	3-Cyano-4-ethyl-6-hydroxy-1,6-dimethyl-2-piperidone (63)		566
5-Methyl-3-hexen-2-one and Diethyl malonate	NaOC_2H_5	5-Isopropylcyclohexane-1,3-dione (80)		422, 567, 568
3,4-Dimethyl-3-penten-2-one and Diethyl malonate	NaOC_2H_5	4,5,5-Trimethylcyclohexane-1,3-dione		569
5-Hydroxy-4-hepten-3-one and Cyanoacetamide	None	3-Cyano-4,6-diethyl-2-pyridone		370
4-Hydroxy-5-thoxy-3-penten-2-one and Cyanoacetamide	Piperidine	3-Cyano-4-ethoxymethyl-6-methyl-2-pyridone (81)		477

<i>4-Hydroxy-3-ethyl-3-penten-2-one and</i> <i>Cyanacetamide</i>	None	3-Cyano-5-ethyl-4,6-dimethyl-2-pyridone	371
<i>Methyl β-Isopropoxyvinyl Ketone and</i> Diethyl malonate	Na	$\text{CH}_3\text{COCH}=\text{CHCH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ and 	389
<i>Methyl 4-Oxo-5-hexenoate and</i> 2-Methylcyclohexane-1,3-dione	NaOCH_3		525
<i>6-Methyl-4-hepten-3-one and</i> Diethyl malonate	NaOC_2H_5	5-Isopropyl-2-methylcyclohexane-1,3-dione (43)	422
<i>4-Ethyl-3-hexen-2-one and</i> Diethyl malonate <i>Cyanacetamide</i>	NaOC_2H_5 NaOC_2H_5	5,5-Diethylcyclohexane-1,3-dione (50) 3-Cyano-4,4-diethyl-6-hydroxy-6-methyl-2-piperidone (75)	570 566
<i>n-Propyl β-Ethoxyvinyl Ketone and</i> <i>Cyanacetamide</i>	Piperidine	3-Cyano-6-n-propyl-2-pyridone (64)	564

Note: References 491-1045 are on pp. 545-555.

TABLE II—*Continued*
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>Isopropyl β-Ethoxyvinyl Ketone and</i> Cyanoacetamide	Piperidine	3-Cyano-6-isopropyl-2-pyridone (77)	564
3- <i>n</i> -Amyl-3-buten-2-one and Methyl hexyl ketone	KOH, CH ₃ OH	4,6-Di-(<i>n</i> -amyl)-3-methyl-2-cyclohexenone (23, 33)	418, 552
6-Methyl-5-nonen-4-one and Diethyl malonate	NaOC ₂ H ₅	2-Ethyl-5-methyl-5- <i>n</i> -propylcyclohexane-1,3-dione	571
<i>Decane-2,4-dione (enol) and</i> Cyanoacetamide §§	None		555
<i>β-Ethoxyvinyl <i>n</i>-Amyl Ketone and</i> Cyanoacetamide	Piperidine	6- <i>n</i> -Amyl-3-cyano-2-pyridone (68)	564

8-Methyl-7-tridecen-8-one and Diethyl malonate	NaOC_2H_5	$A = n\text{-C}_5\text{H}_{11}\text{COCH}_2\text{C}(\text{CH}_3)\text{C}_5\text{H}_{11}\text{-}n$ 5- <i>n</i> -Amyl-2- <i>n</i> -butyl-5-methylcyclohexane-1,3- dione (60)	572
Cyanacetamide	NaOC_2H_5	$A\text{CH}(\text{CN})\text{CONH}_2$ (64)	572
1-Hydroxymethyleneheptadecan-2-one and Diethyl acetone-1,3-dicarboxylate	NaOC_2H_5	Diethyl 2-hydroxy-4- <i>n</i> -pentadecylisophthalate (52)	427
13-Methyl-12-tricosen-11-one and Diethyl malonate	NaOC_2H_5	$A = n\text{-C}_{10}\text{H}_{21}\text{C}(\text{CH}_3)\text{CH}_2\text{COC}_{10}\text{H}_{21}\text{-}n$ 5- <i>n</i> -Decyl-5-methyl-2- <i>n</i> -nonylcyclohexane-1,3- dione (60)	572
Cyanacetamide	NaOC_2H_5	$A\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ †††	572

Note: References 491–1045 are on pp. 545–555.

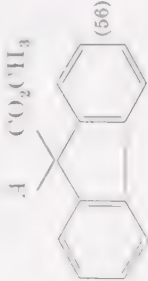
†† A mixture of ethyl cyanoacetate and ammonia or the appropriate amine was used in these experiments.


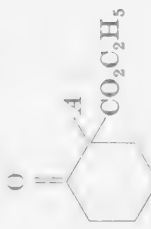
††† A mixture of trioxymethylene and the ketone was used.

‡ This product was obtained after acid hydrolysis and esterification.

TABLE III

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>Vinyl Phenyl Ketone* and</i> Dimethyl malonate	NaOCH_3	$A = \text{C}_6\text{H}_5\text{COCH}_2\text{CH}_2-$ $A\text{CH}(\text{CO}_2\text{CH}_3)_2$ (70), $(A)_2\text{C}(\text{CO}_2\text{CH}_3)_2$ (small)	573
Methyl fluoromethyl-carboxylate	KOH	 (56)	544
Ethyl acetoacetate	NaOC_2H_5	6-Carboxy-3-phenyl-2-cyclohexen-1-one	574
Malononitrile	NaOCH_3	$(A)_2\text{C}(\text{CN})_2$	228
Methyl cyanoacetate	NaOCH_3	$(A)_2\text{C}(\text{CN})\text{CO}_2\text{CH}_3$ (70)	228
Cyanoacetamide	NaOCH_3	$(A)_2\text{C}(\text{CN})\text{CONH}_2$	228
Methyl benzyl ketone	NaOCH_3	3,6-Diphenyl-2-cyclohexen-1-one	574
Decybenzoin	NaOCH_3	$\text{C}_6\text{H}_5\text{COCH}(A)\text{C}_6\text{H}_5$ (60)	575
Dibenzyl ketone	NaOC_2H_5	2,3,6-Triphenyl-2-cyclohexen-1-one	574
Benzyl <i>p</i> -biphenyl ketone	NaOCH_3	$\text{C}_6\text{H}_5\text{CH}(A)\text{C}(\text{OC}_6\text{H}_4\text{C}_6\text{H}_5)_2$	575
Nitroacetamide	NaOCH_3	$(A)_3\text{CNO}_2$	228
Phenylbutyramide	NaOCH_3	$\text{C}_6\text{H}_5\text{CH}(A)\text{NO}_2$ (82)	576
<i>Hydroxymethyleneacetophenone and</i> Ethyl acetoacetate	$[\text{CH}_3\text{COCH}(\text{CO}_2\text{C}_2\text{H}_5)]_n\text{Na}$	Ethyl 3-hydroxybiphenyl-4-carboxylate (42)	577
Diethyl acetone-1,3-dicarboxylate	NaOC_2H_5	Diethyl 3-hydroxybiphenyl-2,4-dicarboxylate (59)	427
$\text{CH}_3\text{CO}-\text{NH}-\text{CH}_2\text{COOCH}_3$	None	3-Acetyl-2-methyl-6-phenylpyridine	422
$\text{CH}_3\text{CO}-\text{NH}-\text{CH}_2\text{COOCH}_2\text{C}_6\text{H}_5$	None	3-Benzoyl-2-methyl-6-phenylpyridine	442
Nitroacetate	$\text{C}_6\text{H}_5\text{COCH}=\text{CHONa}$	β -Hydroxy- γ -nitrobutyrophenone	545
<i>(Methoxymethylene)acetophenone and</i> Ethyl acetoacetate	$[\text{CH}_3\text{COCH}(\text{CO}_2\text{C}_2\text{H}_5)]_n\text{Na}$	Ethyl 3-hydroxybiphenyl-4-carboxylate (42)	577

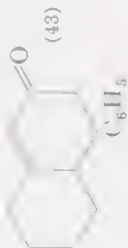
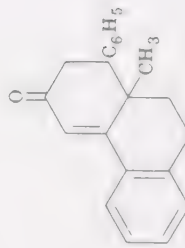
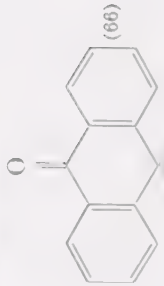
<i>Benzylidenemalonone and</i> <i>Trimethyl malonate</i> Dimethyl malonate	NaOCH_3 $\text{Na, NaOC}_2\text{H}_5$ KOH, acetal	$A = \text{CH}_3\text{COCCH}_2\text{CHC}_6\text{H}_5$ $A\text{CH}(\text{CO}_2\text{CH}_3)_2$ 5-Phenylcyclohexane-1,3-dione (75) or its 4-carbethoxy derivative $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (84)	71 4, 578 579 483, 517, 518, 580, 30
Ethyl phenylacetate	NaOC_2H_5	4,5-Diphenylcyclohexane-1,3-dione	82
Ethyl cyclopentanone-2-carboxylate	KOC_2H_5		409
Ethyl cyclohexanone-2-carboxylate	KOC_2H_5		409
Ethyl cyanacetate Ethyl α-cyanobutyrate Ethyl α-cyanopropionate Cyanacetamide	NaOC_2H_5 NaOC_2H_5 NaOC_2H_5 <i>sec. Amine</i> NaOC_2H_5	$A\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (91) $\text{CH}_3\text{CH}_2\text{C}(A)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (23) $\text{C}_4\text{H}_9\text{C}(A)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (78) 3-Cyano-6-hydroxy-6-methyl-4-phenyl-2-piperidone 3-Cyano-2-ke(o-6-methyl-4-phenyl-2,3,4,5-tetrahydro)pyridine	121 581 121 439 439, 224
Acetonitrile $\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{CN}$ Benzyl cyanide Deoxybenzoin	KOH, acetal NaOC_2H_5 NaOCH_3 NaOC_2H_5	$A\text{CH}_2\text{CN}$ (82) 3-Cyano-2,6-dimethyl-4-phenylpyridine (12) $\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$ (87) $\text{C}_6\text{H}_5\text{COCCH}(A)\text{C}_6\text{H}_5$	483, 517, 518 440 121 416



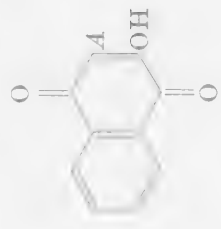
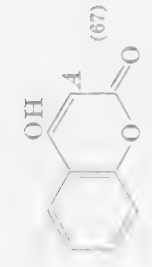
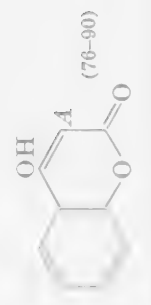
Note: References 491-1045 are on pp. 545-555.

* *p*-A chloropropiophenone was actually used in these condensations.

TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>Benzylidenecetone (Cont.) and</i>		$A = \text{CH}_3\text{COCH}_2\text{CHC}_6\text{H}_5$	
Cyclohexanone	NaNH_2	 (43)	98
2-Methylcyclohexanone	NaNH_2	 (44)	98
Anthrone	Piperidine	 (66)	582
Nitromethane	$(\text{C}_2\text{H}_5)_2\text{NH}$	ACH_2NO_2 (58)	209
1-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$(\text{CH}_3\text{CH}_2\text{CH}(A)\text{NO}_2$ (two isomers: total, 90)	209
2-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$(\text{CH}_3)_2\text{C}(A)\text{NO}_2$ (77)	209
Ethyl nitroacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{O}_2\text{NCH}(\text{CH}_3)\text{CH}_2\text{H}_5$ (51)	134
	$(\text{C}_2\text{H}_5)_3\text{N}(\text{CH}_2\text{CH}_2)_3\text{OH}$	$\text{O}_2\text{NCH}(A)\text{CO}_2\text{C}_2\text{H}_5$	

Fluorene	NaOC_2H_5	 (2)	376
2,7-Dibromofluorene	NaOC_2H_5	 (11)	376
2-Hydroxy-1,4-naphthoquinone	Pyridine		583
4-Hydroxycoumarin	Piperidine	 (67)	169, 584
	NH_3 , <i>t</i> -amines	 (76-90)	585
Triethyl phosphonoacetate	NaOC_2H_5	$(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (48)	124




Note: References 491-1045 are on pp. 545-555.

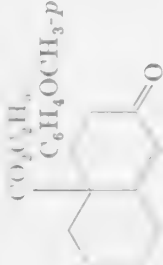
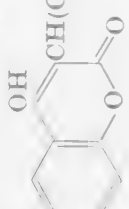
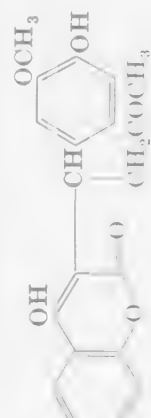
† The product was obtained as a salt of the *aci* form.

TABLE III (continued)

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

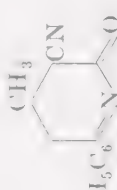
A. Substituted Benzylideneacetones

Substituent in 	Addend	Catalyst	Product (Yield, %)	References
2-Hydroxy	Ethyl acetacetate	NaOC_2H_5	4-Acetyl-2-methyl-1,4-benzopyran	434
	Ethyl methylacetacetate	NaOC_2H_5	4-Acetyl-2,3-dimethyl-1,4-benzopyran (52)	38
	Ethyl phenylacetacetate	NaOC_2H_5	4-Acetyl-2-methyl-3-phenyl-1,4-benzopyran	38
$A = \text{ArylCHCH}_2\text{COCH}_3$				
2-Methoxy	2-Hydroxybenzylideneacetone	NaOC_2H_5		586
	Ethyl acetacetate	Aq. NaOH	2-(or 4)-Carbethoxy-5-(o-methoxyphenyl)-3-methyl-2-cyclohexen-1-one	434
4-Methoxy	Diethyl malonate	NaOC_2H_5	5-(o-Methoxyphenyl)cyclohexane-1,3-dione	587
	Diethyl malonate	NaOC_2H_5	5-(p-Methoxyphenyl)cyclohexane-1,3-dione (59)	587
4-Methoxy	Ethyl acetacetate	Piperidine	$\text{CH}_3\text{COCH(A)CO}_2\text{C}_2\text{H}_5$ (55)	588
	Triethyl ethane-1,2,2-tricarboxylate	NaOC_2H_5		109

Ethyl cyclopentanone-2-carboxylate	KOC_2H_5	$\text{CH}_3\text{COCH}_2\text{CH}(\text{C}_6\text{H}_4\text{OCH}_3)\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ $\text{CH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$	409
Ethyl cyclohexanone-2-carboxylate	KOC_2H_5		409
Ethyl cyanoacetate	NaOC_2H_5	4-Cyano-5-(<i>p</i> -methoxyphenyl)cyclohexane-1,3-dione (90)	589
Deoxybenzoin	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{C}_6\text{H}_5$	589 416
4-Hydroxycoumarin	Pyridine		169
3-Nitro	NaOC_2H_5	5-(<i>m</i> -Nitrophenyl)cyclohexane-1,3-dione	590
4-Nitro	NaOC_2H_5	5-(<i>p</i> -Nitrophenyl)cyclohexane-1,3-dione	590
2-Chloro	NaOC_2H_5	5-(<i>o</i> -Chlorophenyl)cyclohexane-1,3-dione (27)	587
4-Hydroxy-3-methoxy	Pyridine		169
2,3-Dimethoxy	NaOC_2H_5	$\text{CH}_3\text{CH}_2\text{C}(\text{CN})(\text{A})\text{CO}_2\text{C}_2\text{H}_5$	581
4-Dimethylamino	Aq. NaOH	2-Carbethoxy-3-(<i>p</i> -dimethylaminophenyl)-5-hydroxy-5-methylcyclohexan-1-one	285
4-Isopropyl	NaOC_2H_5	5-(<i>p</i> -Isopropylphenyl)cyclohexane-1,3-dione (60)	578

Note: References 491-1045 are on pp. 545-555.

TABLE III—*Continued*
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethylideneacetophenone and</i> <i>(cyclohexanone)</i>	NaOC_2H_5		591
<i>Hydroxymethylene-p-methylacetophenone and</i> $(\text{CH}_3\text{C}(=\text{NH})(\text{CH}_2\text{CO}_2\text{C}_6\text{H}_5)$ $(\text{CH}_3\text{C}(=\text{NH})(\text{CH}_2\text{COCH}_3)$ $(\text{CH}_3\text{C}(=\text{NH})(\text{CH}_2\text{COCOC}_6\text{H}_5)$	None None None	Ethyl 2-methyl-6-(p-tolyl)pyridine-3-carboxylate 3-Acetyl-2-methyl-6-(p-tolyl)pyridine 3-Benzoyl-2-methyl-6-(p-tolyl)pyridine	557 442, 557 442
α -Hydroxymethylencethyl Phenyl Ketone and $(\text{CH}_3\text{C}(=\text{NH})(\text{CH}_2\text{CO}_2\text{C}_6\text{H}_5)$	None	Ethyl 2,3-dimethyl-6-phenylpyridine-3-carboxylate	557
<i>Benzoylacetone (Enol) and</i> Diethyl acetate-1,3-dicarboxylate	NaOC_2H_5	Diethyl 3-hydroxy-5-methylbiphenyl-2,4-dicarboxylate (47)	427
Cyanoacetamide	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Cyano-6-methyl-4-phenyl-2-pyridone and 3-cyano-4-methyl-6-phenyl-2-pyridone	371, 592
Diethyl oxammonate	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Carbethoxy-4-methyl-6-phenyl-2-pyridone (low)	370
Malonamide	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Cyano-4-methyl-6-phenyl-2-pyridone	370
3-Amino-1-phenyl-2-buten-1-one and Malonamide	None	2-Hydroxy-4-methyl-6-phenylpyridine-3-carboxamide	391, 398
Diethyl oxammonate	NaOC_2H_5	3-Cyano-6-methyl-4-phenyl-2-pyridone	391
Cyanoacetamide	None	3-Cyano-4-methyl-6-phenyl-2-pyridone	391

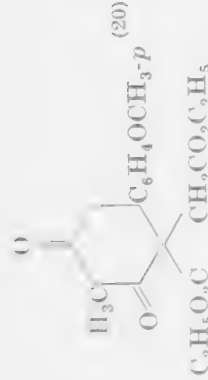


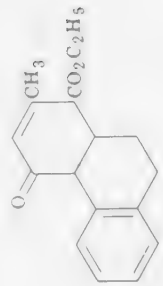
$\text{NaCNH}_2\text{CONHCH}_3$	None	3-Cyano-1,4-dimethyl-6-phenyl-2-pyridone and 3-cyano-4-methyl-6-phenyl-2-pyridone	391
<i>Ethyl Styryl Ketone and</i> <i>Pyruvate-amide</i>	NaOC_2H_5	4-Carboethoxy-2-methyl-5-phenylcyclohexane- 1,3-dione (79)	423
<i>Isobutyl phenylacetate</i>	NaOC_2H_5	2-Methyl-5-phenylcyclohexane-1,3-dione (80) 2-Methyl-4,5-diphenylcyclohexane-1,3-dione (21, 32)	422 423, 422
<i>Ethyl Phenacyl Ketone (Enol) and</i> <i>Pyruvate-amide</i>	None	3-Cyano-4-ethyl-6-phenyl-2-pyridone	371
1-Hydroxy-5-phenyl-1-penten-3-one and Cyanoacetamide	Piperidine	$\text{C}_{14}\text{H}_{12}\text{N}_2\text{O}$, 5-cyano-6-hydroxy-2-phenethyl- pyridine (?)	172
1-Phenyl-2-methyl-2-buten-1-one and Nitroacetamide	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}(\text{CH}_3)\text{CH}(\text{CH}_3)\text{CH}_2\text{NO}_2$ (63)	560
<i>Isopropyl 2-methyl-2-buten-1-one and</i> <i>Nitroacetamide</i>	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}_2\text{C}(\text{CH}_3)_2\text{CH}_2\text{NO}_2$ (76)	560
5-Phenyl-3-penten-2-one† and Dimethyl malonate	NaOC_2H_5	5-Benzylcyclohexane-1,3-dione	593
4-Phenyl-4-methoxy-3-buten-2-one and Pyruvate-amide	NaOC_2H_5 ; $\text{C}_6\text{H}_5\text{N}_2\text{NH}$	3-Cyano-6-methyl-4-phenyl-2-pyridone (30)	592
1-Phenyl-3-ethoxy-2-buten-1-one and Pyruvate-amide	NaOC_2H_5	3-Cyano-4-methyl-6-phenyl-2-pyridone	592

Note: References 491-1045 are on pp. 545-555.

† This ketone was produced *in situ* by isomerization of 5-phenyl-4-penten-2-one.

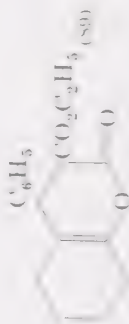
TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES				
Reactants	Catalyst	Product (Yield, %)	References	
<i>p</i> -Methylbenzoylacetone (Enol) and Cyanacetamide	$(C_2H_5)_2NH$	3-Cyano-4-methyl-6- <i>p</i> -tolyl-2-pyridone (80) and 3-cyano-6-methyl-4- <i>p</i> -tolyl-2-pyridone (in small amount from the isomeric enol)	594	
$NCC_2H_5CONHCH_3$	$(C_2H_5)_2NH$	3-Cyano-1,6-dimethyl-4- <i>p</i> -tolyl-2-pyridone	594	
1-Phenyl-3-methylamino-2-buten-1-one and Cyanacetamide		3-Cyano-4-methyl-6-phenyl-2-pyridone and 3-cyano-1,4-dimethyl-6-phenyl-2-pyridone	391	
Ethoxymethyleneacetophenone and Diethyl malonate	Na enolate of the ester	Ethyl 6-phenylcoumalin-3-carboxylate (44)	577	
<i>n</i> -Propyl Styryl Ketone and Diethyl malonate	$NaOC_2H_5$	4-Carbethoxy-2-ethyl-5-phenylcyclohexano-1,3- dione (41)	423	
Isopropyl Styryl Ketone and Diethyl malonate	$NaOC_2H_5$	$(CH_3)_2CHCOCH_2CH(C_6H_5)CH(CO_2C_2H_5)_2$ (79)	319	
Ethyl <i>p</i> -Methoxystyryl Ketone and Diethyl malonate	$NaOC_2H_5$	4-Carbethoxy-5-(<i>p</i> -methoxyphenyl)-2-methylcyclo- hexano-1,3-dione (44)	595	
Ethyl <i>p</i> -Cyanostyryl Ketone and Diethyl malonate	$NaOC_2H_5$	4-Cyano-5-(<i>p</i> -methoxyphenyl)cyclohexano-1,3- dione (55)	589	

Propylacetate 1,1,2-tricarboxylate	NaOC_2H_5		109
Cyclopropyl Styryl Ketone and Nitracetate	NaOCH_3	$\text{CH}_2=\text{CHCOCH}_2\text{CH}(\text{C}_6\text{H}_5)$ 	138
1-Phenyl-3-cyclopropyl-2-propen-1-one and Nitracetate	NaOCH_3	$\text{CH}_2=\text{CHCH}(\text{CH}_2\text{CO}_2\text{CH}_3)$ 	138
1-Acetyl-3,4-dihydronaphthalene and Ethyl acetate	NaOC_2H_5		596
3-Acetyl-4-phenyl-3-buten-2-one and Phenylacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Acetyl-4,5-diphenyl-5-nitropentan-2-one (84)	29
n-Butyl Styryl Ketone and Diethyl malonate	NaOC_2H_5	4-Carboxy-5-phenyl-2-n-propylcyclohexane-1,3-dione (35)	423

Note: References 491-1045 are on pp. 545-555.

TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES			
Reactants	Catalyst	Product (Yield, %)	References
<i>Vinyl p-n-Propoxyphenyl Ketone and</i>			
Nitromethane	NaOH	$A = p\text{-}n\text{-C}_3\text{H}_7\text{OC}_6\text{H}_4\text{C}(\text{OCH}_2\text{CH}_2\text{—})$	597
Phenylnitromethane	NaOCH_3	$(A)_2\text{CHNO}_2$ (73)	597
Cyanacetamide	NaOCH_3	$\text{C}_6\text{H}_5\text{CH}(A)\text{NO}_2$ (71) $\text{NCC}(A)_2\text{CONH}_2$ (83)	597
<i>Benzalpinacolone and</i>			
Dimethyl malonate	NaOCH_3	$A = (\text{CH}_3)_3\text{CCOCH}_2\text{CHC}_6\text{H}_5$	598
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{CH}_3)_2$ (82)	598, 599
Methyl <i>p</i> -nitrophenylacetate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (97, 70§)	600
Ethyl <i>p</i> -nitrophenylacetate	NaOC_2H_5	$p\text{-O}_2\text{NC}_6\text{H}_4\text{CH}(A)\text{CO}_2\text{CH}_3$	600
Nitromethane	NaOCH_3	$p\text{-O}_2\text{NC}_6\text{H}_4\text{CH}(A)\text{CO}_2\text{C}_2\text{H}_5$ ACH_2NO_2 (80–90)	601
<i>Isopropyl p-Methoxystyryl Ketone and</i>			
Diethyl malonate	Enolate	$(\text{C}_6\text{H}_5)_2\text{CHC}(\text{OCH}_2\text{CH}(\text{C}_6\text{H}_4\text{OCH}_3)_p)\text{C}(\text{H}_2\text{CO}_2\text{H})$	30
<i>3-Ethoxy-1-p-tolyl-2-buten-1-one and</i>			
Cyanacetamide	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Cyano-1-methyl-6- <i>p</i> -tolyl-2-pyridone (quant.)	594
<i>2-Benzylidenecyclohexanone and</i>			
Diethyl malonate	Enolate		602
	Enolate	Ethyl β -(2-oxocyclohexyl)hydrocinnamate (70)	603

p-Methoxybenzylidenecyclohexanone and

Diethyl malonate

Na

602

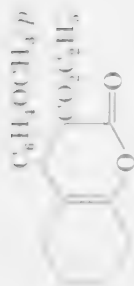
n-Hexyl Styryl Ketone and

Diethyl malonate

NaOC₂H₅

423

4-Carboethoxy-2-pentyl-5-phenylcyclohexane-1,3-dione (45)



1,2-Diphenyl-2-propen-1-one and

Benzyl *p*-chlorophenyl ketoneKOH, CH₃OH $A = C_6H_5C(OC_6H_4Cl)_pCH_2-$ Benzyl *p*-tolyl ketoneKOH, CH₃OH

604

Benzyl *p*-anisyl ketoneKOH, CH₃OHC₆H₅CH(A)COC₆H₄OCCH₃-*p* (74)

Deoxybenzoin

KOH, CH₃OH

604

Phenyl *p*-chlorobenzoyl ketoneKOH, CH₃OH*p*-ClC₆H₄CH(A)COC₆H₅ (77)Phenyl *p*-methylbenzoyl ketoneKOH, CH₃OH*p*-CH₃C₆H₄CH(A)COC₆H₅ (71)Phenyl *p*-dimethylaminobenzylKOH, CH₃OH*p*-(CH₃)₂NC₆H₄CH(A)COC₆H₅ (86)

ketone

604

Dibenzoylmethane (Enol) and

Cyanacetamide

NaOC₂H₅

370, 592

(C₂H₅)₂NH

3-Cyano-4,6-diphenyl-2-pyridone (5-20)

370, 592

Piperidine

3-Cyano-4,6-diphenyl-2-pyridone (55-70)

370, 592

Vinyl *p*-Biphenyl Ketone and

Deoxybenzoin

NaOC₂H₅


575


p-C₆H₅C₆H₄COCCH₂CH₂CH(C₆H₅)COC₆H₅

Note: References 491-1045 are on pp. 545-555.

§ The acid was isolated in this experiment.

TABLE III—Continued
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>Chalcone, $C_6H_5CH=CHCOC_6H_5$, and</i>			
$A = C_6H_5CHCH_2COC_6H_5$			
Dimethyl malonate	NaOC ₂ H ₅	ACH(CO ₂ CH ₃) ₂ (80, 94)	75, 404
	Piperidine	ACH(CO ₂ CH ₃) ₂ (poor)	71
Diethyl malonate	Piperidine; 0.1 equiv. NaOC ₂ H ₅ ; KOH, acetal 1 equiv. NaOC ₂ H ₅	ACH(CO ₂ C ₂ H ₅) ₂ (71, 93, 98)	30, 55, 125, 483, 517, 518
		Diethyl 5-benzoyl-2,4,6-triphenyl-4 cyclohexenyl- 1,1-dicarboxylate (70)	55
Diethyl methylmalonate	Piperidine, NaOC ₂ H ₅	AC(CH ₃)(CO ₂ C ₂ H ₅) ₂ (80)	55, 125, 51
	Na	Retrosession products	396, 607
Diethyl ethylmalonate	NaOC ₂ H ₅	Retrosession products	125
Diethyl phenylmalonate	NaOC ₂ H ₅	AC(C ₆ H ₅)(CO ₂ C ₂ H ₅) ₂ (94)	403
Diethyl succinate	NaOC ₂ H ₅	ACHCO ₂ H —CH ₂ CO ₂ H	73
Methyl phenylacetate	NaOCH ₃	C ₆ H ₅ CH(A)(CO ₂ CH ₃)	163, 608
Ethyl phenylacetate	NaOC ₂ H ₅	C ₆ H ₅ CH(A)(CO ₂ C ₂ H ₅) (92); compound C ₄₀ H ₃₄ O ₈	82, 125
Diethyl α -phenylbutyrate	NaOC ₂ H ₅	C ₆ H ₅ C(C ₂ H ₅)(CO ₂ C ₂ H ₅) ₂ (3)	125
<i>p</i> -O ₂ NC ₆ H ₄ CH ₂ CO ₂ CH ₃	NaOCH ₃	<i>p</i> -O ₂ NC ₆ H ₄ CH(A)CO ₂ CH ₃ (95)	600
<i>p</i> -O ₂ NC ₆ H ₄ CH ₂ CO ₂ C ₂ H ₅	NaOC ₂ H ₅	<i>p</i> -O ₂ NC ₆ H ₄ CH(A)CO ₂ C ₂ H ₅	600
<i>p</i> -O ₂ NC ₆ H ₄ CH ₂ CO ₂ C ₄ H ₉	NaOC ₂ H ₅	<i>p</i> -O ₂ NC ₆ H ₄ CH(A)(CO ₂ C ₄ H ₉) _{<i>n</i>}	600
Ethyl acetoacetate	NaOC ₂ H ₅ ; piperidine		125, cf. 19

$\text{CH}_3\text{COCH}(\text{C}_6\text{H}_5)\text{COOC}_6\text{H}_5$	NaOC_2H_5		125
Ethyl benzyloacetate	Piperidine, NaOC_2H_5 , Na in C_6H_5	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (94) Compound $\text{C}_{30}\text{H}_{34}\text{O}_8$	125 403
Methyl cyanoacetate	NaOCH_3	$\text{ACH}(\text{CN})\text{CO}_2\text{CH}_3$ and $(\text{A})_2\text{C}(\text{CN})\text{CO}_2\text{CH}_3$ (83)	609
Ethyl cyanoacetate	NaOC_2H_5	$(\text{A})_2\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (91)	121
Ethyl n-butylcyanoacetate	NaOC_2H_5	$\text{AC}(\text{C}_4\text{H}_9-n)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (78)	121
Cyanoacetamide	NaOCH_3	$\text{ACH}(\text{CN})\text{CONH}_2$ (72)	610
$(\text{H}_2\text{C})_3\text{N}(\text{H})\text{CH}_2\text{CN}$	Piperidine or $(\text{C}_2\text{H}_5)_2\text{NH}$ 1 equiv, NaOC_2H_5 NaOC_2H_5	3-Cyano-6-hydroxy-4,6-diphenyl-2-piperidone (75) 3-Cyano-4,6-diphenyl-3,4-dihydro-2-pyridone (87) 5-Cyano-6-methyl-2,4-diphenylpyridine and its 1,4-dihydro derivative	439 439 440
Malonitrile	NaOCH_3	$\text{ACH}(\text{CN})_2$	610
Benzyl cyanide	NaOCH_3	$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN}$ (two isomers: 87; 40 and 30)	72, 611
Phenylacetaldehyde	NaOCH_3	$\text{C}_6\text{H}_5\text{C}(\text{A})_2\text{CN}$ (94)	612
Diethyl ketone	NaOC_2H_5	$\text{C}_6\text{H}_5\text{CHOCH}_2\text{CH}(\text{C}_6\text{H}_5)\text{CH}(\text{C}_6\text{H}_5)\text{CO}_2\text{H}$ (30)	163
Phenolone	NaOC_2H_5	$\text{CH}_3\text{CH}(\text{A})\text{COC}_2\text{H}_5$ and $\text{CH}_3\text{C}(\text{A})_2\text{COC}_2\text{H}_5$ (90-100)	207
Acetophenone	NaOC_2H_5	$(\text{CH}_3)_3\text{COCH}(\text{A})_2$ (69)	207
Propiophenone	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}(\text{A})_2$ (27) and $\text{C}_6\text{H}_5\text{COC}(\text{A})_3$ (25)	125
n-Bulxyphenone	NaOC_2H_5	$\text{CH}_3\text{CH}(\text{A})\text{COC}_6\text{H}_5$ (54) and $\text{CH}_3\text{C}(\text{A})_2\text{COC}_6\text{H}_5$ (27)	207
Isobutylphenone	NaOC_2H_5	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{COC}_6\text{H}_5$ (19) and $\text{CH}_3\text{CH}_2\text{C}(\text{A})_2\text{COC}_6\text{H}_5$ (58)	207
Deoxybenzoin	NaOC_2H_5	$(\text{CH}_3)_2\text{C}(\text{COC}_6\text{H}_5)\text{CH}(\text{C}_6\text{H}_5)\text{CH}(\text{A})\text{COC}_6\text{H}_5$ (30)	207
Dibenzoylmethane	NaOC_2H_5	$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{COC}_6\text{H}_5$ $(\text{C}_6\text{H}_5\text{CO})_2\text{CH}(\text{A})$ (1)	13 125

Note: References 491-1045 are on pp. 545-555.

|| Two isomeric acids and a non-acidic product, $\text{C}_{29}\text{H}_{26}\text{O}_4$, of unknown structure were obtained.

TABLE III—Continued

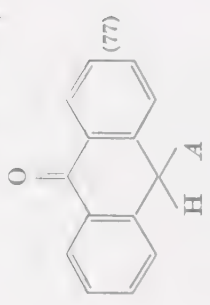
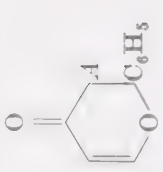
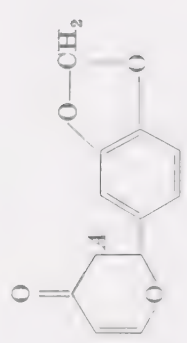
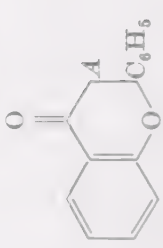
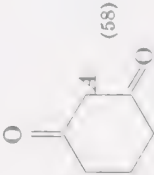

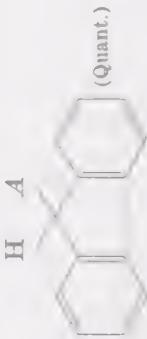

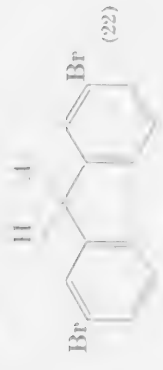
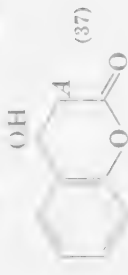
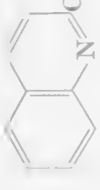

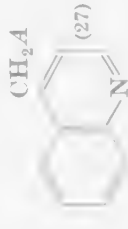
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES			References
Reactants	Catalyst	Product (Yield, %)	
Chalcone, $C_6H_5CH=CHCOC_6H_5$, (Cont.) and		$A = C_6H_5CH(CH_2COC_6H_5)$	
Anthrone	$NaOCH_3$; NaOH, ethanol; <i>sec</i> -amines	 (77)	163, 613
2-Phenyl-2,3-dihydro- γ -pyrone	NaOH, ethanol		614
2-(3,4'-Methylenedioxyphenyl)- 2,3-dihydro- γ -pyrone	Na		614
2-Phenyl-2,3-dihydrobenzo- γ - pyrone	Aq. NaOH; $NaNH_2$; Na		615

TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>Chalcone</i> , $C_6H_5CH=CHCOC_6H_5$, (Cont.) and		$A = C_6H_5CHCH_2COC_6H_5$	
			618
Cyclohexane-1,3-dione	Piperidine		
Nitromethane	$NaOCH_3$; NH_3 , ethanol $(C_2H_5)_2NH$ CaH_2 , CH_3OH	ACH_2NO_2 (75, 88) and $(A)_2CHNO_2$ (small) $(A)_2CHNO_2$ (two isomers, 77) ACH_2NO_2 (65–92)	620, 209, 619 621 466a
Nitroethane	$(C_2H_5)_2NH$; $NaOCH_3$	$CH_3CH(A)NO_2$ (two isomers: 78 + 11; quant.)	209, 620
1-Nitropropane	$(C_2H_5)_2NH$ CaH_2 , CH_3OH	$CH_3CH_2CH(A)NO_2$ (97)	209
2-Nitropropane	$(C_2H_5)_2NH$; $NaOCH_3$; CaH_2 , CH_3OH	$CH_3CH_2CH(A)NO_2$ (65–92) $(CH_3)_2C(A)NO_2$ (92–96)	466a 209, 466a, 620
Ethyl nitroacetate	$(C_2H_5)_2NH$	$O_2NCH(A)CO_2C_2H_5$ (94)	622
Benzyl <i>p</i> -tolyl sulfone	$NaOCH_3$	$C_6H_5CH(A)SO_2C_6H_4CH_3$ - <i>p</i> (two isomers: 15, 11)	74
Cyclopentadiene	Na derivative; piperidine	 $CH(C_6H_5)CH(A)COC_6H_5$ (Small)	376
Fluorene	Pyridine, $NaOH$, H_2O	 H A (Quant.)	362, 623


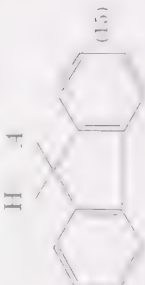
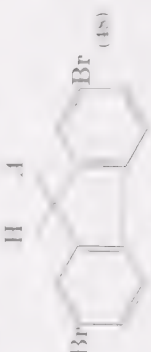
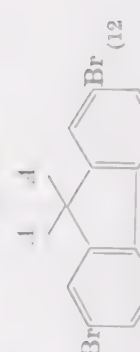
NaOC_2H_5		376
NaOC_2H_5		376
4-Hydroxycoumarin		169
2-Methylpyridine	Tri- and tetra-molecular condensation products	374
2-Methylquinoline	 or 	374
NaNH_2		374

Note: References 491-1045 are on pp. 545-555.

TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES

B. Substituted Chalcones

Substituent(s) in 	Addend	Catalyst	Product (Yield, %)	References
3-Br 4-Br 4'-Br	CH_3NO_2 CH_3NO_2 $\text{CH}_2(\text{CO}_2\text{CH}_3)_2$ $\text{CH}_2(\text{CO}_2\text{C}_2\text{H}_5)_2$ CH_3NO_2 1,4-Pentadiene	NaOCH_3 NaOCH_3 NaOCH_3 NaOC_2H_5 NaOC_2H_5 NaOC_2H_5 ; NaNH_2 , liq. NH_3	$A = \text{Appropriately Substituted}$ $(\text{C}_6\text{H}_5\text{CHCH}_2\text{COOC}_6\text{H}_5)$ $A = \text{CH}_2\text{NO}_2$ $A = \text{CH}_2\text{NO}_2$ $A = \text{CH}(\text{CO}_2\text{CH}_3)_2$ (92) $A = \text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ $A = \text{CH}_2\text{NO}_2$ (87) $(\text{CH}_2=\text{CH})_2\text{CH}_2$ (4) $(\text{CH}_2=\text{CH})_2\text{CH}_2$ (11)	621 621 624 624 625 376
Fluorene		NaOC_2H_5	 (15)	376
2,7-Dibromofluorene		NaOC_2H_5	 (18) and  (12)	376

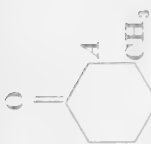



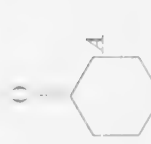
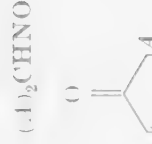
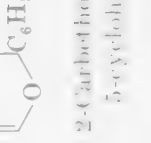
[illegible]

Note: References 491–1045 are on pp. 545–555.

TABLE III (Continued)



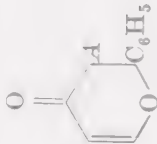
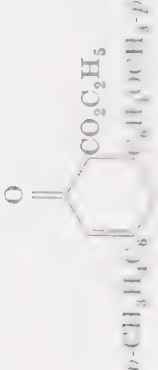
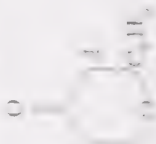
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES			
Substituent(s) in	Addend	Catalyst	Product (Yield, %)
			$A =$ Appropriately Substituted $C_6H_5CHCH_2COOC_6H_5$
2-HO (Cont.)	Cyclopentanone	$(C_2H_5)_2NH$	
	Cyclohexanone	$NaOH$, ethanol	
2'-HO	4-Hydroxycoumarin	Pyridine	
4-CH ₃ O	$CH_2(CO_2CH_3)_2$ $CH_3COCH_2CO_2C_2H_5$ $NCCH_2CONH_2$	$NaOCH_3$ $NaOC_2H_5$ Na enolate	$A = CH(CO_2CH_3)_2$ (good) 2-Carbethoxy-5- <i>p</i> -methoxyphenyl-5-phenyl-5-cyclohexen-1-one 3-Cyano-2-hydroxy-4- <i>p</i> -methoxyphenyl-6-phenyl-4,5-dihydro-pyridine
	Cyclopentanone	<i>sec</i> -Amines	



3'-CH ₃	2-Methylcyclohexanone	<i>sec</i> -Amines; KOH, C ₆ H ₅ OH		616
	Deoxybenzoin	KOH, CH ₃ OH; NaOCH ₃	(Two isomers) 	604, 629
	Nitroacetophenone	NaOCH ₃		621
4'-CH ₃	2-Phenyl-2,3-dihydro-γ-pyrone	NaOCH ₂ H ₅		614
3'-CH ₃	Cyclohexanone	NaOH, ethanol		613
4'-CH ₃	CH ₃ N ₂ O ₂	NaOCH ₃		621
	2-Phenyl-2,3-dihydro-γ-pyrone	NaOH, ethanol		614
4'-CH ₃	CH ₃ COCH ₂ CO ₂ C ₆ H ₅	NaOCH ₂ H ₅	2- <i>o</i> -Carboxy- <i>o</i> -3-methyl-5- <i>p</i> -tolyl-5-cyclohexen-1-one	630

Note: References 491–1045 are on pp. 545–555.

TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES			
Substituent(s) in	Addend	Catalyst	Product (Yield, %)
			$\text{C}_6\text{H}_5\text{CH}(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$ —
4'-CH ₃ (Cont.)	N(C ₂ H ₅) ₃ CONH ₂	Piperidine	3-Cyano-6-hydroxy-4-phenyl-6- <i>p</i> -tolyl-2-piperidone (75)
	CH_3NO_2 $\text{CH}_2(\text{CO}_2\text{CH}_3)_2$	NaOC_2H_5 NaOCH_3 NaOC_2H_5	3-Cyano-2-keto-4-phenyl-6- <i>p</i> -tolyl-2,3,4,5-tetrahydropyridine (90) $(A)_2\text{CHNO}_2$ $\text{ACH}(\text{CO}_2\text{CH}_3)_2$
4,4'-Dimethoxy	2-Phenyl-2,3-dihydro-5-pyrone	Na	
4,4'-H ₃ CO, 4'-CH ₃	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOC ₂ H ₅	
	2-Phenyl-2,3-dihydro-5-pyrone	Na	

References

439

499

621

627

614

628

614

Reactants	Catalyst	Product (Yield, %)	References
α -Bromobenzylideneacetophenone and p -O ₂ NC ₆ H ₄ CH ₂ CN	NaOCH ₃	$\text{H}_3\text{C}_6\text{CH} \begin{array}{l} \diagup \text{C}(\text{CN})\text{H}_6\text{N}(\text{O}_2)_2\text{p} \\ \diagdown \text{CHCOOC}_6\text{H}_5 \end{array}$ (Mixture of stereoisomers)	631
3,4-Methylenediorthostyryl <i>n</i> -Hexyl Ketone and Toluene	NaOC ₂ H ₅	$\text{CH}_3(\text{COCH}(\text{C}_6\text{H}_5)\text{C}_2\text{H}_5$ $3,4\text{-CH}_2\text{O}_2\text{C}_6\text{H}_3\text{CH}(\text{CH}_2(\text{OC}_6\text{H}_{13})_n$ (At 5°, 65%)	481
		$n\text{-H}_{13}\text{C}_6 \begin{array}{c} \text{O} \\ \\ \text{C}_6\text{H}_3\text{O}_2\text{CH}_2\text{-3,4} \end{array}$ (At reflux 50%, together with some of the 6-carbethoxy derivative)	632, 633

Note: References 491–1045 are on pp. 545–555.

TABLE III—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC KETONES		Catalyst	Product (Yield, %)	References
Reactants				
<i>trans</i> -Dibenzoylethylene and			$A = C_6H_5COCH_2CHCOC_6H_5$	
Diethyl benzylmalonate	$NaOC_2H_5$	$C_6H_5C(H_2C(A)C(O_2C_2H_5)_2$ (20) 1,2,3-Tribenzylpropane (1) $C_6H_5COCH_2CH(A)COC_6H_5$ (62)	—	58
Acetophenone	$NaOC_2H_5$			634
1,2-Dibenzoyl-ethane	$NaOC_6H_5$			634
1,1-Dibenzoyl-ethane (Enol) and				
Cyanacetamide	$(C_2H_5)_2NH$		3-Cyano-5-methyl-4,6-diphenyl-2-pyridone	592
3,4-Diphenyl-3-buten-2-one and				
Phenylmethylmalonate	$(C_2H_5)_2NH$		1-Nitro-1,2,3-triphenylpentan-4-one (68)	29
2-Benzoyl-1-phenylpropene and				
Dimethyl malonate	$NaOC_2H_5$		$C_6H_5COCH(CH_3)CH(C_6H_5)CH(CO_2CH_3)_2$ (two isomers: 52 + 10)	76
2-Methoxy-1,3-diphenyl-2-propen-1-one and				
Cyanoacetamide	$NaOCH_3$		3-Cyano-5-methoxy-4,6-diphenyl-2-pyridone	631
Benzoyl- <i>p</i> -tolylmethane (Enol) and				
Cyanacetamide	$(C_2H_5)_2NH$		3-Cyano-4-phenyl-6- <i>p</i> -tolyl-2-pyridone (34) and 3-cyano-6-phenyl-4- <i>p</i> -tolyl-2-pyridone (47)	370


Deoxybenzoin	NaOC_2H_5		416
<i>Styryl Phenethyl Ketone and</i>		$A = \text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{COCH}_2\text{CH}(\text{C}_6\text{H}_5)\text{COC}_6\text{H}_5$	
Dimethyl malonate	NaOCH_3	$\text{ACH}(\text{CO}_2\text{CH}_3)_2$	423
Diethyl malonate	NaOC_2H_5	4-Carboethoxy-2-benzyl-5-phenylcyclohexanone-1,3-dione (60)	198
3-Benzoyl-4-phenyl-3-buten-2-one and			
Phenyltrimethane	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Benzoyl-5-nitro-4,5-diphenylpentan-2-one (38)	29
$p\text{-CH}_3\text{C}_6\text{H}_4\text{COC}_6\text{H}_4\text{C}(\text{C}(\text{C}_6\text{H}_5)_2)=\text{NHC}_6\text{H}_5$	None	5-Acetyl-2-methyl-4,6-diphenyl-3- <i>p</i> -toluoyl-3,4-dihydropyridine	398
3-Methoxy-3-phenyl-1- <i>p</i> -tolyl-2-propen-1-one and			
Cyanacetamide	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Cyano-4-phenyl-6- <i>p</i> -tolyl-2-pyridone	370
3-Methoxy-1-phenyl-3- <i>p</i> -anisyl-2-propen-1-one and			
Cyanacetamide	$(\text{C}_2\text{H}_5)_2\text{NH}$	3-Cyano-4- <i>p</i> -anisyl-6-phenyl-2-pyridone	594
Fluorenylideneacetophenone [†] and			
Acetophenone	KOH, acetal	9,9-Diphenacylfluorene	635
5-Mesitylacenaphthylene and			
Diethyl malonate	NaOC_2H_5	5-Mesitylacenaphthene-1-acetic acid** (50)	636

Note: References 491-1045 are on pp. 545-555.


[†] The unsaturated ketone was formed *in situ* from fluorenone and acetophenone.

** The acid was obtained after hydrolysis of the adduct.

TABLE IV

MICHAEL CONDENSATIONS WITH ETHYLENIC KETONES OF THE DIBENZYLIDENE- AND DICINNAMYLDENE-ACETONE TYPE			References
Reactants	Catalyst	Product (Yield, %)	
<i>Dibenzylidenemalonate</i>			
Dimethyl malonate	Piperidine NaOCH ₃	$A\text{CH}(\text{CO}_2\text{CH}_3)_2$ (59)	198
Diethyl malonate	Piperidine NaOCH ₃	Dimethyl 2,6-diphenyl-4-oxocyclohexane-1,1-dicarboxylate	198
Ethyl acetoacetate	(C ₂ H ₅) ₂ NH NaOCH ₃	$A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	198
Methyl cyanoacetate	NaOH	Diethyl 2,6-diphenyl-4-oxocyclohexane-1,1-dicarboxylate	198
Ethyl cyanoacetate	NaOC ₂ H ₅	CH ₃ COCH(A)CO ₂ C ₂ H ₅ (38)	21
		4-Carbomethoxy-4-cyano-3,5-diphenylcyclohexan-1-one (72)	198, 199
		4-Carbomethoxy-4-cyano-3,5-diphenylcyclohexan-1-one	199
		4-Carbethoxy-4-cyano-3,5-diphenylcyclohexan-1-one (88)	200
<i>Dibenzylidenecyclohexanone</i>			
3-Methylcyclohexanone	(C ₂ H ₅) ₂ NH		616
Benzyl cyanide	NaOCH ₃	γ -Cinnamoyl- α,β -diphenylbutyronitrile (two isomers), and 4-cyano-3,4,5-triphenylcyclohexan-1-one (total 44)	952
<i>Nitromethane</i>			
	NaOCH ₃	4-Cyano-3,4,5-triphenylcyclohexan-1-one (52) 4-Nitro-3,5-diphenylcyclohexan-1-one or 4-Cyano-3,4,5-triphenylcyclohexan-1-one (52)	198

Substituted Dibenzylacetones


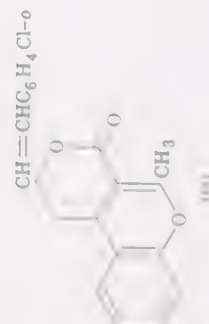

Substituent(s) in	Addend	Catalyst	Substituents in Product (Yield, %)	Reference
				
2-Cl	CH ₃ COCH ₂ (CO ₂ C ₂ H ₅) ₂	NaOC ₂ H ₅ ; piperidine	3- <i>o</i> -ClC ₆ H ₄ CH=CH—, 5-C ₆ H ₅ , 6-C ₂ H ₅ O ₂ C— (35)	201
3-Cl	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOC ₂ H ₅ ; piperidine	3- <i>m</i> -ClC ₆ H ₄ CH=CH—, 5-C ₆ H ₅ , 6-C ₂ H ₅ O ₂ C— (88)	201
4-Cl	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOC ₂ H ₅ ; piperidine	3- <i>p</i> -ClC ₆ H ₄ CH=CH—, 5-C ₆ H ₅ , 6-C ₂ H ₅ O ₂ C—	201
2,3'-Di-Cl	CH ₃ COCH ₂ (CO ₂ C ₂ H ₅) ₂	NaOCH ₃	3- <i>o</i> -ClC ₆ H ₄ —, 5- <i>m</i> -ClC ₆ H ₄ CH=CH—, 6-C ₂ H ₅ O ₂ C—	201
2,4'-Di-Cl	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOCH ₃	3- <i>o</i> -ClC ₆ H ₄ —, 5- <i>p</i> -ClC ₆ H ₄ CH=CH—, 6-C ₂ H ₅ O ₂ C—	201
3,4'-Di-Cl	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOCH ₃	3- <i>m</i> -ClC ₆ H ₄ —, 5- <i>p</i> -ClC ₆ H ₄ CH=CH—, 6-C ₂ H ₅ O ₂ C—	198
4-CH ₃	CH ₂ (CO ₂ CH ₃) ₂	Piperidine	<i>p</i> -CH ₃ OC ₆ H ₄ CH=CHCOCH ₂ CH ₂ (C ₆ H ₅)- CH(CO ₂ CH ₃) ₂	198
		NaOCH ₃	3- <i>p</i> -Anisyl-4,4-dicarbomethoxy-5- phenylcyclohexan-1-one	198

Note: References 491–1045 are on pp. 545–555.

TABLE IV—Continued

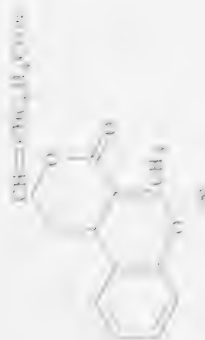
MAHALI CONDENSATIONS WITH ETHYLENIC KEYTONES OF THE DIBENZYLIDENE- AND DICINNAMYLIDENE-ACETONE TYPE

Substituted Dibenzylidenacetones—Continued

Substituent(s) in	Addend	Catalyst	Substituents in Product (Yield, %)	References
 2-HO, 2'-Cl	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOH, aq. ethanol	3- <i>o</i> -(C ₆ H ₄)CH=CH-5- <i>o</i> -HO(C ₆ H ₄)-, 6-C ₂ H ₅ O ₂ C— (28)	203
 CH=CHC ₆ H ₄ Cl- <i>o</i>				203
 CH ₂ COCH=CHC ₆ H ₄ Cl- <i>o</i>	C ₆ H ₅ COCH ₂ CO ₂ C ₂ H ₅	NaOC ₂ H ₅		203

$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}m\text{-}(\text{C}_6\text{H}_4)\text{CH}=\text{CH}-$, $6\text{-C}_2\text{H}_5\text{O}_2\text{C}-$ (3)	203
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}p\text{-}(\text{C}_6\text{H}_4)\text{CH}=\text{CH}-$, $6\text{-C}_2\text{H}_5\text{O}_2\text{C}-$ (33)	203
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}m\text{-}(\text{C}_6\text{H}_4)\text{CH}=\text{CH}-$, $6\text{-C}_2\text{H}_5\text{O}_2\text{C}-$ (65)	204
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}p\text{-}(\text{C}_6\text{H}_4)\text{CH}=\text{CH}-$, $6\text{-C}_2\text{H}_5\text{O}_2\text{C}-$ (70)	204
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}p\text{-}(\text{C}_6\text{H}_4)\text{CH}=\text{CH}-$, $5\text{-}m\text{-}\text{ClC}_6\text{H}_4-$, $6\text{-C}_2\text{H}_5\text{O}_2\text{C}-$ (55)	204
$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}p\text{-}(\text{C}_6\text{H}_4)\text{CH}=\text{CH}-$, $5\text{-}p\text{-}\text{ClC}_6\text{H}_4-$, $6\text{-C}_2\text{H}_5\text{O}_2\text{C}-$ (45)	204

2-HO, 4-Cl



2-HO, 4-Cl



3-Cl, 4'-HO

4-Cl, 4'-HO

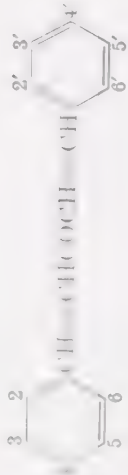
3-Cl, 4'-CH3O

4-Cl, 4-CH3O

TABLE IV—Continued

MICHAEL CONDENSATIONS WITH ETHYLENE KETONES OF THE DIBENZYLIDENE- AND DICINNAMYLIDENE-ACETONE TYPE

Substituted Dibenzylideneacetones—Continued

Substituent(s) in	Addend	Catalyst	Substituents in Product (Yield, %)	References
	$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}o\text{-HOC}_6\text{H}_4\text{CH=CH-}$, $5\text{-}o\text{-HOC}_6\text{H}_4\text{-}$ (24)	202, 586
2-HO, 2'- CH_3O	$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}o\text{-CH}_3\text{OC}_6\text{H}_4\text{CH=CH-}$, $5\text{-}o\text{-HOC}_6\text{H}_4\text{-}$	202
2,2'-Di- CH_3O	$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}o\text{-(CH}_3\text{OC}_6\text{H}_4\text{CH=CH-)}$, $5\text{-}o\text{-CH}_3\text{OC}_6\text{H}_4\text{-}$ (88)	202
4,4'-Di- CH_3	$\text{CH}_3\text{COCH}_2\text{COCH}_3$	NaOH , aq. ethanol	$3\text{-}o\text{-CH}_3\text{OC}_6\text{H}_4\text{CH=CH-}$, $5\text{-}o\text{-CH}_3\text{OC}_6\text{H}_4\text{-}$, 2- $\text{CH}_3\text{CO-}$	202
	$\text{CH}_2(\text{CO}_2\text{CH}_3)_2$	NaOCH_3	4,4-Dicarbomethoxy-3,5-di- <i>p</i> -methoxy-phenylcyclohexan-1-one	198
	$\text{NCCH}_2\text{CO}_2\text{CH}_3$	NaOCH_3	3,5-Di-(<i>p</i> -methoxyphenyl)-4-carbomethoxy-4-cyanocyclohexan-1-one	199
4,4'-Di-(CH_3) ₂ N	$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$3\text{-}p\text{-(CH}_3)_2\text{NC}_6\text{H}_4\text{CH=CH-}$, $5\text{-}p\text{-(CH}_3)_2\text{NC}_6\text{H}_4\text{-}$, 6- $\text{C}_2\text{H}_5\text{O}_2\text{C-}$	203
2-HO, 4'-(CH_3) ₂ N	$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	KOH , aq. ethanol	$3\text{-}o\text{-HOC}_6\text{H}_4\text{CH=CH-}$, $5\text{-}p\text{-(CH}_3)_2\text{NC}_6\text{H}_4\text{-}$, 6- $\text{C}_2\text{H}_5\text{O}_2\text{C-}$	203
	$\text{NCCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOH , aq. ethanol	$p\text{-(CH}_3)_2\text{NC}_6\text{H}_4\text{CH=CH-CHOCCH}_2\text{-}$, $\text{CH(C}_6\text{H}_4\text{OH-}o\text{)CH(CO}_2\text{H)}_2^*$	203

Reactants	Catalyst	Product (Yield, %)	References
<i>Benzylidenecinnamylidenecetone and</i>			
Dimethyl malonate	NaOCH ₃	4,4-Dicarbomethoxy-3-phenyl-5-styrylcyclohexan-1-one	198
<i>p-Methoxybenzylidenecinnamylidenecetone and</i>			
Dimethyl malonate	NaOCH ₃	4,4-Dicarbomethoxy-3- <i>p</i> -methoxyphenyl-5-styrylcyclohexan-1-one	198
<i>Dicinnamylidenecetone and</i>			
Dimethyl malonate	NaOCH ₃	4,4-Dicarbomethoxy-3,5-distyrylcyclohexan-1-one	198
<i>2,6-Dibenzylidenecyclohexanone and</i>			
Cyanomethyl malonate	NaOC ₂ H ₅	Compound C ₂₃ H ₂₂ N ₂ O ₂	224


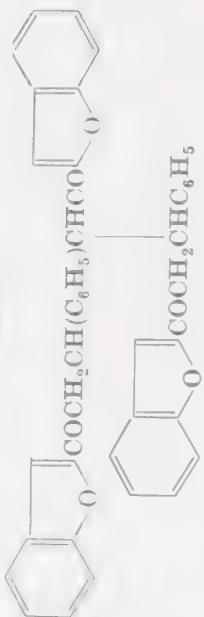
* The acid was obtained after hydrolysis of the adduct.

2-CH ₃ O, 4-(CH ₃) ₂ N	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOH, aq. ethanol	3- <i>o</i> -CH ₃ OC ₆ H ₄ CH=CH—, 5- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ —, 6-C ₂ H ₅ O ₂ C—	265
2-HO, 3-CH ₃ O, 4-(CH ₃) ₂ N	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOH, aq. ethanol	3-(2-HO-3-CH ₃ OC ₆ H ₃ CH=CH—, 5- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ —, 6-C ₂ H ₅ O ₂ C—	265
2-HO, 4-CH ₃ O, 4-(CH ₃) ₂ N	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOH, aq. ethanol	3- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ CH=CH—, 5-(2-HO-4-CH ₃ OC ₆ H ₃)—, 6-C ₂ H ₅ O ₂ C—	265
2-HO, 5-CH ₃ O, 4-(CH ₃) ₂ N	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOH, aq. ethanol	3-(2-HO-5-CH ₃ OC ₆ H ₃)CH=CH—, 5- <i>p</i> -(CH ₃) ₂ NC ₆ H ₄ —, 6-C ₂ H ₅ O ₂ C—	265
2-OC ₂ H ₅ , 4-CH ₃	CH ₃ COCH ₂ CO ₂ C ₂ H ₅	NaOCH ₃	3- <i>p</i> -ClC ₆ H ₄ CH=CH—, 5- <i>o</i> -CH ₃ OC ₆ H ₄ —, 6-C ₂ H ₅ O ₂ C— (57)	263

TABLE V
MICHAEL CONDENSATIONS WITH UNSATURATED KETONES CONTAINING HETEROCYCLIC RINGS

Reactants	Catalyst	Product (Yield, %)	References
<i>Furfurylideneacetone</i> and			
Benzyl cyanide	NaOCH_3	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	
1-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN}$ (81)	121
2-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (75)	209
Triethyl phosphonoacetate	NaOC_2H_5	$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (95)	209
		$(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (9)	124
<i>Furfurylideneacetophenone</i> and			
Diethyl malonate	NaOC_2H_5	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	
Acetophenone	NaOC_2H_5	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	
Nitromethane	NaOCH_3	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	
1-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	
2-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	
Phenylnitromethane	NaOCH_3	$\text{A} = \text{CH}_2=\text{CH}-\text{O}-\text{CH}(\text{CH}_2\text{COCH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3$	

TABLE V—Continued
MICHAEL CONDENSATIONS WITH UNSATURATED KETONES CONTAINING HETEROCYCLIC RINGS

Reactants	Catalyst	Product (Yield, %)	References
<i>Benzylidene-2-acetylcoumarone</i> and 2-Acetylcoumarone†	Aq. NaOH	 and 	637
<i>Hydroxymethylene-2-acetylthiophene</i> and Diethyl acetone-1,3-dicarboxylate	NaOC ₂ H ₅	Diethyl 2-hydroxy-4-(α-thienyl)isophthalate (61)	427
<i>Hydroxymethylene-2-acetylpyridine</i> and Diethyl acetone-1,3-dicarboxylate	NaOC ₂ H ₅	Diethyl 2-hydroxy-4-(α-pyridyl)isophthalate (76)	427
<i>Phenyl β-(4-Quinolyl)vinyl Ketone</i> and Acetophenone‡	NaOH	1,5-Diphenyl-3-(4-quinolyl)pentane-1,5-dione (87)	638

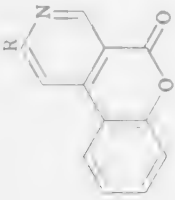
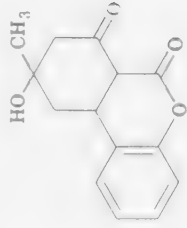
Note: References 491–1045 are on pp. 545–555.

† A mixture of benzaldehyde and 2-acetylcoumarone was used.

‡ A mixture of acetophenone and quinoline-4-carboxaldehyde was used.

TABLE VI

MICHAEL CONDENSATIONS WITH 3-ACETYLCUMARINS AND RELATED COMPOUNDS

Reactants	Catalyst	Product (Yield, %)	References
3-Acetylcoumarin and Cyanacetamide	None	 unless complete structure is shown R = 3-Coumarinyl (45-52)*	211
Acetone	Piperidine		212
Methyl ethyl ketone	$\text{NH}_3(\text{NCCCH}_2\text{CONH}_2)^\dagger$	R = CH_3 (32)	211
Acetophenone	$\text{NH}_3(\text{NCCCH}_2\text{CONH}_2)^\dagger$	R = C_6H_5 (42)	211
3-Acetylcoumarin	$\text{NH}_3(\text{NCCCH}_2\text{CONH}_2)^\dagger$	R = C_6H_5 (21)	211
	$\text{NH}_3(\text{NCCCH}_2\text{CONH}_2)^\dagger$	R = 3-Coumarinyl	212

* The cyanoacetamide could be replaced by malonamide, formamide, or urea without changing the product. The same product was obtained when piperidine was used as a catalyst. The earlier report (ref. 213) that the product with cyanoacetamide and piperidine was 3-acetyldihydrocoumarin-4-(α -cyanoacetamide) could not be confirmed.

† In these experiments cyanoacetamide was present; its decomposition furnished the ammonia.

TABLE VI—Continued

MICHAEL CONDENSATIONS WITH 3-ACYLCUMARINS AND RELATED COMPOUNDS

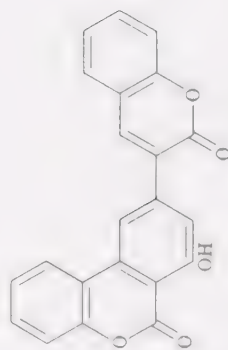
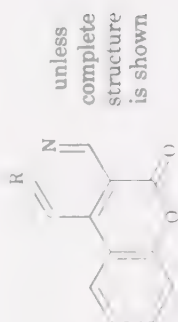
References

Product (Yield, %)

Catalyst

Reactants

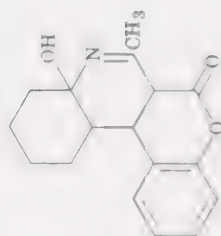
3-Acetylcoumarin (Cont.) and



Piperidine

... Acetylcoumarin

(18)

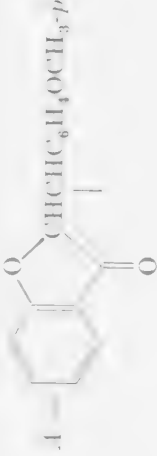



(47)

 $\text{NH}_3(\text{NCCH}_2\text{CONH}_2)^\dagger$

Cyclohexanone

211

3-Benzoylcoumarin and cyanacetamide	Piperidine	5-Benzoyldihydrocoumarin-4-(α -cyanoacetamide)	213
7-Hydroxycoumarin and cyanacetamide	Piperidine	7-Hydroxydihydrocoumarin-4-(α -cyanoacetamide) (90)	639
7-Methoxycoumarin and cyanacetamide	Piperidine	7-Methoxydihydrocoumarin-4-(α -cyanoacetamide) (90)	639
2-(<i>p</i> -Methoxyphenyl)hydrocoumarin-2-one; and Ethyl acetoacetate Deoxybenzoin	NaOC_2H_5 NaOC_2H_5	 $\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ $\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{C}_6\text{H}_5$	214 214
Cyclohexanone	NaOC_2H_5		214

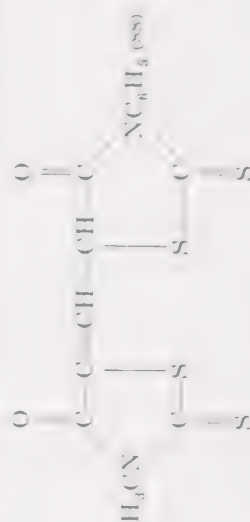
Note: References 491-1045 are on pp. 545-555.

1. In these experiments cyanacetamide was present; its decomposition furnished the ammonia.

2. The corresponding 5-methoxy compound behaves analogously with ethyl acetoacetate, deoxybenzoin, and cyclohexanone; ref. 214a.

TABLE VI—Continued

MICHAEL CONDENSATIONS WITH 3-ACYLCOTUMARINS AND RELATED COMPOUNDS			
Reactants	Catalyst	Product (Yield, %)	References
<i>γ</i> -Pyrone and furfuryl malonate	NaOC_2H_5	Ethyl <i>p</i> -hydroxybenzoate	215
Alkylidenetherhodanines and Rhodanine §	NH_4OH , NH_4Cl	α, α -Bis-(2-thio-4-ketotetrahydro-5-thiazolyl)ethane and homologs (22-55)	216
5-Ethoxymethylene-3-methylrhodanine and 3-Methylrhodanine	<i>t</i> -Amines	5,5'-Methyldiynbis-(3-methylrhodanine) (34-69)	640

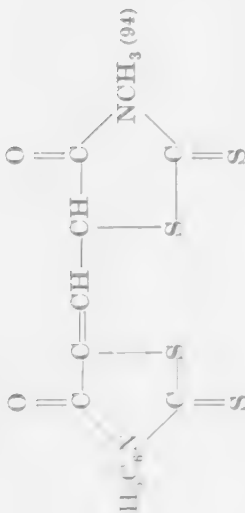
 $(\text{C}_2\text{H}_5)_3\text{N}$

3-Ethoxymethylene-

 $\text{NC}_6\text{H}_5(\text{ss})$

640

5-Ethoxymethylene-3-phenylrhodanine and

3-Methylrhodanine	$(C_2H_5)_3N$		640
-------------------	---------------	--	-----

3,3'-Ethylenebis-(5-ethoxymethylmerhodanine) and

3-Methylrhodanine	$(C_2H_5)_3N$	Salt of 3,3'-ethylenebis-5-(2"-thiono-4"-keto-3"-methyl-5"-thiazolidyl)methylmerhodanine (50)	640
3-Phenylrhodanine	$(C_2H_5)_3N$	Salt of 3,3'-ethylenebis-5-(2"-thiono-4"-keto-3"-phenyl-5"-thiazolidyl)methylmerhodanine (37)	640

Pyrazol blue and

1-Phenyl-3-methyl-2-pyrazolin-5-one	None	1,1',1"-Triphenyl-3,3',3"-trimethyl-(4,4',4"-ter-2-pyrazoline)-5,5',5"-trione	641
1- <i>p</i> -Bromophenyl-3-methyl-2-pyrazolin-5-one	None	1,1'-Diphenyl-1"-(<i>p</i> -bromophenyl)-3,3',3"-trimethyl-(4,4',4"-ter-2-pyrazoline)-5,5',5"-trione	641

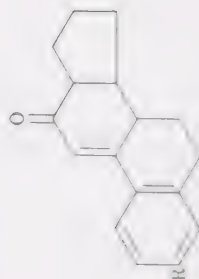
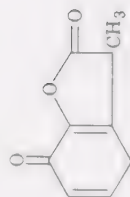
Note: References 491-1045 are on pp. 545-555.

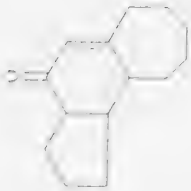


* The actual ingredients used were rhodanine and various aliphatic aldehydes.

TABLE VII

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES

Reactants	Catalyst	Product (Yield, %)	References
<i>2-Hydroxymethylenecyclopentanone and</i>			
Ethyl acetate	NaOC_2H_5	5-Indanol-6-carboxylic acid (18)	427
Diethyl acetone-1,3-dicarboxylate	NaOC_2H_5	Diethyl 5-indanol-4,6-dicarboxylate (92)	427
Ethyl β -aminocrotonate		6-Methyl-2,3-dihydro- β -pyridindene*	445
<i>2-Cyclohexen-1-one and</i>			
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (90)	642
Nitromethane	NaOCH_3	ACH_2NO_2 (50)	643
Nitroethane	NaOCH_3	$\text{CH}_3\text{CH}(\text{A})\text{NO}_2$ (57)	643
<i>3-Chloro-2-cyclohexen-1-one and</i>			
Dimethyl methylmalonate	NaOCH_3		436

*1-Acetyl-1-cyclopentene and*

1-Tetralone	NaNH ₂	R = H	98, 217
6-Methoxy-1-tetralone	NaNH ₂	R = CH ₃ O (55)	206
6-Ethoxy-1-tetralone	NaNH ₂	R = C ₂ H ₅ O	217
Cyclohexanone	KOC ₄ H ₉ - <i>t</i>		644
2-Methylenecyclohexanone† and Ethyl acetoacetate	NaOH	2-Oxo-2,3,4,5,6,7,8,10-octahydronaphthalene	528
Methyl ethyl ketone	KOH, CH ₃ OH		645
Cyclohexanone	KOH, CH ₃ OH		645, 646‡

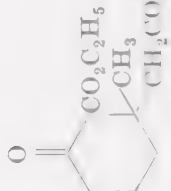
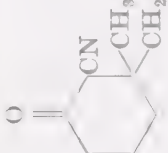
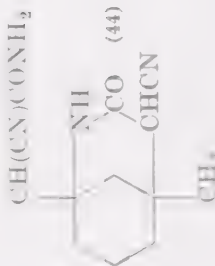
Note: References 491-1045 are on pp. 545-555.

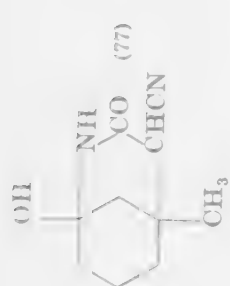


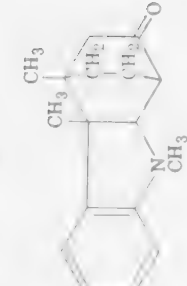
* This product was obtained after hydrolysis and decarboxylation.

† 2-Hydroxymethylcyclohexanone was used in these experiments.

‡ A mixture of cyclohexanone and formaldehyde was employed.

TABLE VII—Continued
MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES

Reactants	Catalyst	Product (Yield, %)	References
3-Methyl-2-cyclohexen-1-one and diethyl malonate	$(C_6H_5CH_2N(CH_3)_3)OCH_3$	 (50)	62, 647, cf. 69, 175
Ethyl acetoacetate	$NaOC_2H_5$	1-Methylbicyclo[3.3.1]nonan-5-ol-7-one	648, 69
Ethyl cyanoacetate	$NaOC_2H_5$	 (43-21)	62, 647, cf. 18, 70
Ethyl cyanoacetate	NH_3	 (44)	649

Cyanoacetamide	Piperidine		649
Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OCH}_3$		652
	Piperidine, 1/15 mole		650
1,3-Dimethylindole	HCl		651

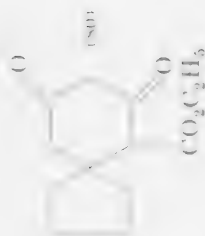
Note: References 491-1045 are on pp. 545-555.

Cyclopentylidenecetone and

Diethyl malonate

NaOC_2H_5

221



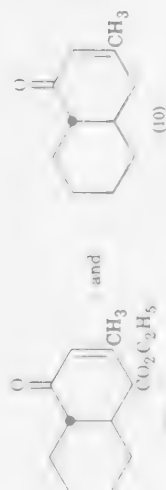
1-Acetyl-1-cyclohexene and

Diethyl malonate

NaOC_2H_5

cis- and *trans*-4-Carboxydecalin-1,3-dione
(7, 87, 60)

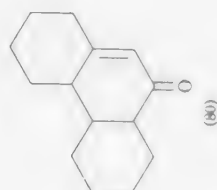
94, 95, 96,
654



Ethyl acetoacetate

NaOC_2H_5

93



Cyclohexanone

NaNH_2

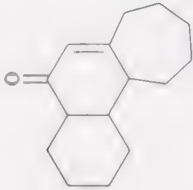
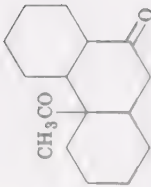
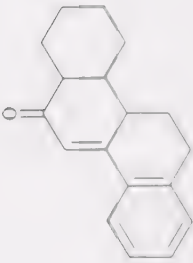
99, cf. 98

Note: References 491-1045 are on pp. 545-555.

At 0° the product is ethyl 9-hydroxy-2-methyl-5,6,7,8,9,10-hexahydroquinoline-3-carboxylate.

TABLE VII—Continued

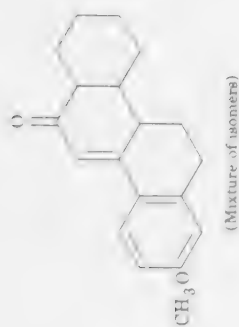
MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES

Reactants	Catalyst	Product (Yield, %)	References
1-Acetyl-1-cyclohexene (Cont.) and Cycloheptanone	$\text{KOC}_4\text{H}_9\text{-}t$	 (56)	644
1-Acetyl-1-cyclohexene	NaNH_2	 (Mixture of isomers)	97
1-Tetralone	NaNH_2		212

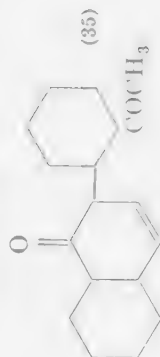
98

 NaNH_2

6-Methoxycyclotetralone



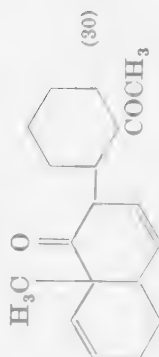
655

 NaNH_2 *cis*-1-Decalone

655

 NaNH_2

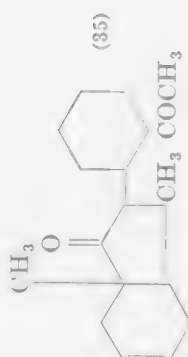
1-Oxo-9-methyl-1,2,5,6,7,8,9,10-octahydronaphthalene



655

 NaNH_2

3,8-Dimethyl-1,7,8,9-tetrahydroindan-1-one



656

 NaOC_2H_5

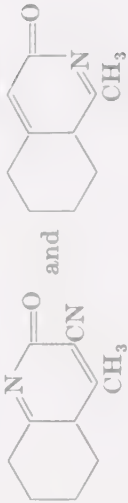
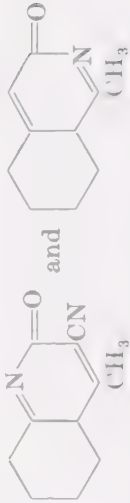


Ethyl acetate

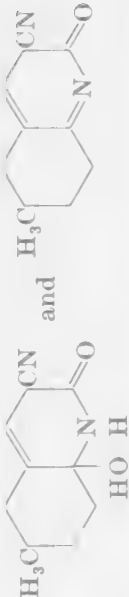
2-Hydroxy-5,6,7,8-tetrahydro-3-naphthoic acid and ethyl α -acetyl- β -(2-ketocyclohexoxy)acrylate

2-Methoxymethylenecyclohexan-1-one and

Note: References 491-1045 are on pp. 545-555.

TABLE VII—Continued

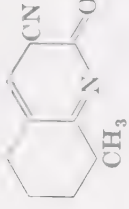

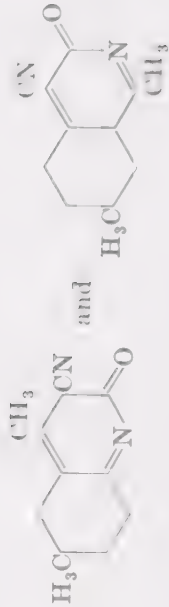
MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES			References
Reactants	Catalyst	Product (Yield, %)	
2-(α -Hydroxyethylidene)cyclohexan-1-one and 100% acetone-1,3-dicarboxylate NaOC_2H_5		5,7-Dicarboethoxy-8-methyl-6-hydroxy- 1,2,3,4-tetrahydronaphthalene (36)	127
Cyanoacetamide	Piperidine; NaOC_2H_5		941
N-Methylcyanoacetamide	Piperidine; NaOC_2H_5		941
3,5-Dimethyl-2-cyclohexen-1-one and ethyl acetate	NaOC_2H_5	1,3-Dimethyl-5-hydroxybicyclo[3.3.1]nonan-7-one	657
2-Hydroxyethylidene-5-methylcyclohexanone and ethyl cyanoacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$		224
Cyanoacetamide	Piperidine; $(\text{C}_2\text{H}_5)_2\text{NH}$		224

2-Aminomethylene-3-methylcyclohexanone and Ethyl cyanoacetate	Na		5-Methyl-3-oxo-2,3,5,6,7,8-hexahydroisoquinoline-4-carbonamide	446
2-Hydroxymethylene-4-methylcyclohexanone and Cyanoacetamide	<i>sec.</i> Amine			224
$\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$	None		Ethyl 2,6-dimethyl-5,6,7,8-tetrahydroquinoline-3-carboxylate	443
$\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{COCH}_3$	None		3-Acetyl-2,6-dimethyl-5,6,7,8-tetrahydroquinoline	653
$\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{COC}_6\text{H}_5$	None		3-Benzoyl-2,6-dimethyl-5,6,7,8-tetrahydroquinoline	443
2-Aminomethylene-4-methylcyclohexanone and Ethyl cyanoacetate	Na		6-Methyl-3-oxo-2,3,5,6,7,8-hexahydroisoquinoline-4-carbonitrile	446
2-Hydroxymethylene-5-methylcyclohexanone and $\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$	None		Ethyl 2,7-dimethyl-5,6,7,8-tetrahydroquinoline-3-carboxylate	443
$\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{COCH}_3$	None		3-Acetyl-2,7-dimethyl-5,6,7,8-tetrahydroquinoline	653
$\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{COC}_6\text{H}_5$	None		3-Benzoyl-2,7-dimethyl-5,6,7,8-tetrahydroquinoline	653
2-Aminomethylene-5-methylcyclohexanone and Ethyl cyanoacetate	Na		7-Methyl-3-oxo-2,3,5,6,7,8-hexahydroisoquinoline-4-carbonitrile	446

Note: References 491-1045 are on pp. 545-555.

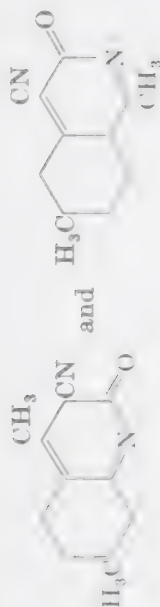
TABLE VII—Continued

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES

Reactants	Catalyst	Product (Yield, %)	References
2-Hydroxymethylene-6-methylcyclohexanone and Cyanooctanamide	<i>sec</i> -Amine		224
$\text{CH}_3\text{C}(\text{CH}_3)=\text{NHC}_6\text{H}_4\text{CO}_2\text{C}_2\text{H}_5$	None	Ethyl 2,8-dimethyl-5,6,7,8-tetrahydroquinoline-3-carboxylate (42)	653
2-Methylene-3-methylcyclohexan-1-one and 3-Methylcyclohexanone	KOH , $\text{C}_2\text{H}_5\text{OH}$		646
2-(α -Hydroxyethylidene)-4-methylcyclohexan-1-one and Cyanooctanamide	Piperidine; NaOC_2H_5		941

2-(α -Hydroxyethylidene)-5-methylcyclohexan-1-one and

(Cyanacetamide)

Piperidine; NaOC_2H_5 

941

2-(α -Hydroxyethylidene)-6-methylcyclohexan-1-one and

(Cyanacetamide)

Piperidine; NaOC_2H_5 

941

2-Hydroxymethylenecycloheptanone and

Diethyl acetone-1,3-dicarboxylate NaOC_2H_5

Diethyl 3-hydroxybicyclo[5.4.0]hendeca-1(6),2,4-triene-2,4-dicarboxylate (61)

428

 $(\text{CH}_3\text{C}(=\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$ None

Ethyl 6-methyl-2,3-dihydropyridindene 7-carboxylate

652

Methyl α -Cyclopentylidenemethyl Ketone andDiethyl malonate NaOC_2H_5

1-Methylspiro[5.4]decane-2,4-dione (low)

220

3-Methylcyclopentylidenemacetone and

Diethyl malonate

 NaOC_2H_5

8-Methylspiro[5.4]decane-2,4-dione

658

Cyclohexylidenemacetone and

Diethyl malonate

 NaOC_2H_5

1-Carbethoxyspiro[5.5]hendecane-2,4-dione (84)

221, 390

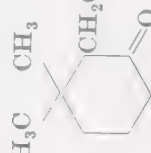
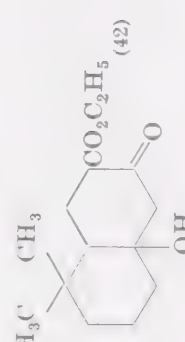
 NaOCH_3

Spiro[5.5]hendecane-2,4-dione (70-80)

654

Note: References 491-1045 are on pp. 545-555.

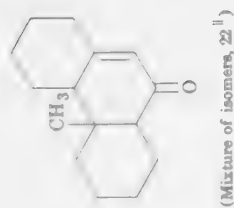
TABLE VII—Continued

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES			References
Reactants	Catalyst	Product (Yield, %)	
<i>2-Methylene-3,3-dimethylcyclohexanone and</i>			
Ethyl acetacetate	NaOC ₂ H ₅	 H_3C CH_3 $\text{CH}_2\text{CH}(\text{COCH}_3)\text{CO}_2\text{C}_2\text{H}_5$ (8-20)	659
		or  H_3C CH_3 $\text{CO}_2\text{C}_2\text{H}_5$ (42)	
<i>2-Hydroxymethylene-4,5-dimethylcyclohexanone and</i>			
$\text{CH}_3\text{C}(\text{OH})=\text{CHCH}_2\text{CO}_2\text{C}_2\text{H}_5$	None	Ethyl 2,6,7-trimethyl-5,6,7,8-tetrahydroquinoline-3-carboxylate	653
<i>Isophorone and</i>			
Nitromethane	Piperidine	5-Nitromethyl-3,3,5-trimethylcyclohexanone (9)	650
<i>1-Acetyl-2-methyl-1-cyclohexene and</i>			
Diethyl malonate	NaOC ₂ H ₅	10-Methyldecalin-1,3-dione (low)	96
		4-Carbethoxy-10-methyldecalin-1,3-dione (good)	660

Cyclohexanone

 KOC_4H_9

401, 384

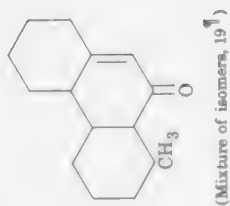


1,4-dimethyl-6-methyl-1-cyclohexene and

Cyclohexanone

 KOC_4H_9

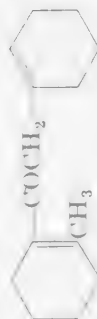
401



Note: References 491-1045 are on pp. 545-555.
 | A 50% yield of

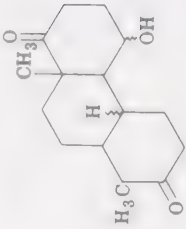
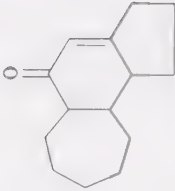
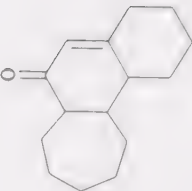


was also obtained. Other authors (ref. 387) describe this compound as the only product of the reaction.
 ¶ In addition, a 46% yield of



was obtained.

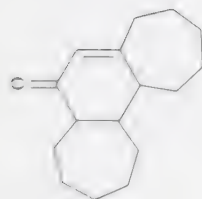
TABLE VII—continued

Reactants	Catalyst	Product (Yield, %)	References
2-Methyl-3-vinyl-2-cyclohexen-1-one and			
2-Methylcyclohexanone-1,3-dione	$(C_2H_5)_2NH$	 (42)	661
1-Acetylcycloheptene and			
Cyclopentanone	$NaOCH_3$	 (26 crude)	644
Cyclohexanone	KOC_4H_9-l	 (55)	644

644

 KOC_4H_9

Cycloheptanone



(41)

2-Hydroxymethylencyclooctanone and

Diethyl acetone-1,3-dicarboxylate

 NaOC_2H_5

128

Diethyl 3-hydroxybicyclo[6.4.0]dodeca-1(6),2,4-triene-2,4-dicarboxylate (59)

3-Methyl-5-n-propyl-2-cyclohexen-1-one and

Nitromethane

Piperidine

650

3-Methyl-3-nitromethyl-5-n-propylcyclohexanone (25)

2-Methylcyclohexylideneacetone and

Diethyl malonate

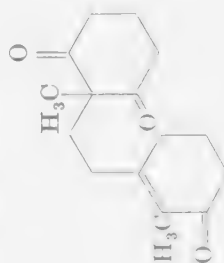
 NaOC_2H_5

220

1-Carboxy-7-methylspiro[5.5]undecane-2,4-dione

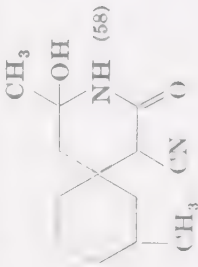
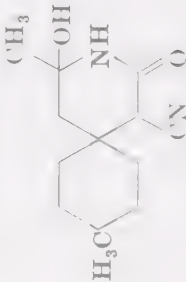
Note: References 491-1045 are on pp. 545-555.

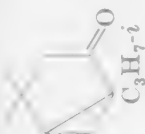

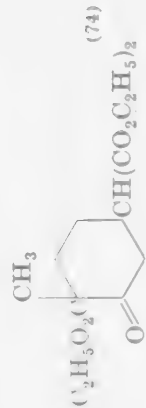
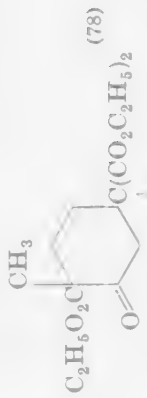
** This product is formed from an intermediate of the formula



which has, however, not been isolated.

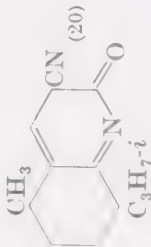
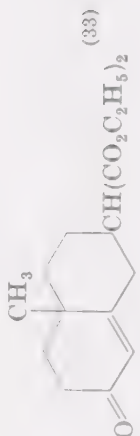
TABLE VII—Continued

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES			
Reactants	Catalyst	Product (Yield, %)	References
<i>3-Methylcyclohexylidenemalonate and</i>			
Diethyl malonate	NaOC_2H_5	8-Methylspiro[5.5]hendecane-2,4-dione	220
Cyanoacetamide	NaOC_2H_5	 (58)	662
<i>4-Methylcyclohexylidenemalonate and</i>			
Ethyl cyanoacetate	NaOC_2H_5	9-Methylspiro[5.5]hendecane-2,4-dione	220
Cyanoacetamide	NaOC_2H_5		662
<i>Carvone and</i>			
Ethyl acetoacetate	NaOC_2H_5	5-Hydroxy-3-isopropenyl-9-methylbicyclo[3.3.1]nonan-7-one (54)	431
Ethyl cyanoacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	Ethyl 2-methyl-5-isopropenylcyclohexanone-3-cyanoacetate (25-33)	20

<i>l</i> -methylolone and				
Diethyl malonate	NaOC_2H_5		(85)	143
1-Acetyl-2,6-dimethylcyclohexene and				
Diethyl malonate	NaOC_2H_5	<i>trans</i> (?) - 8,10-Dimethyldecalin-1,3-dione		96
1-Acetyl-6,6-dimethylcyclohexene and		4-Carbethoxy-8,10-dimethyldecalin-1,3-dione (42)		660, 96
Diethyl α-acetyladipate	Na		(85)	663
6-Carbethoxy-6-methyl-2-cyclohexen-1-one and				
Diethyl malonate	NaOC_2H_5		(74)	664
Diethyl methylmalonate	NaOC_2H_5		(78)	188

Note: References 491-1045 are on pp. 545-555.

TABLE VII—Continued

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES			References
Reactants	Catalyst	Product (Yield, %)	
1-Butyryl-2-methyl-1-cyclohexene and Diethyl malonate	NaOC_2H_5	<i>trans</i> (?) 2-Ethyl-10-methyldecan-1,3-dione	96
2-Hydroxymethylenementhone and γ -Valerolactam	<i>sec</i> -Amine	 (20)	224
2-Hydroxymethylenecamphor and Malonic acid	None	β -Camphorylidenepropionic acid (50)	366
γ -Valerolactam	None	β -Camphorylidenepropionitrile (80)	366
10-Methyl-2-oxo-2,3,4,5,6,10-hexahydronaphthalene and Diethyl malonate	NaOC_2H_5	 (33)	190
2-Hydroxymethylenecyclodecanone and Diethyl 2-oxo-1,3-dicarboxylate	NaOC_2H_5	Diethyl 3-hydroxybicyclo[8.4.0]tetradeca-1(6),2,4-triene-2,4-dicarboxylate (60)	428
2-Phenyl-2-cyclopenten-1-one and Diethyl malonate	NaOC_2H_5	Diethyl 2-phenylcyclopentan-1-one-3-malonate (67)	665
Dibenzyl malonate	KOC_2H_5	3-Oxo-2-phenylcyclopentan-1-acetic acid (53) (2)	666

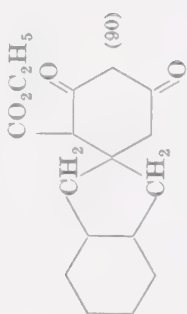
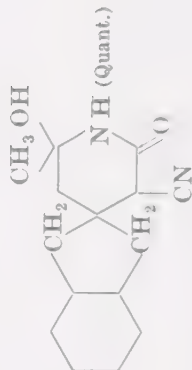
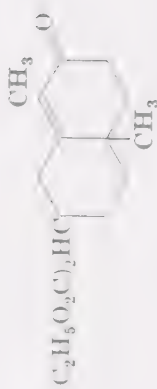
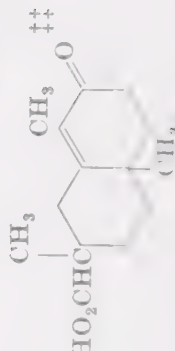
1-Benzoylcyclopentene and Dibenzyl malonate	KOC_4H_9 <i>t</i>	<i>trans</i> (?) 2-Benzoylcyclopentylmalonic acid	667
2-Phenyl-2-cyclohexen-1-one and Diethyl malonate	NaOC_2H_5	Diethyl <i>trans</i> -2-phenylcyclohexan-1-one-3-malonate (96)	105, 106, 668, 669
Dibenzyl malonate	KOC_4H_9 <i>t</i>	Dibenzyl <i>trans</i> -2-phenylcyclohexan-1-one-3-malonate (96)	108, 669
Methyl cyanoacetate	NaOC_2H_5	Methyl 2-phenylcyclohexan-1-one-3-cyanoacetate (80)	106, 668
Benzyl cyanoacetate Nitromethane Methyl nitroacetate	KOC_4H_9 <i>t</i> $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}^+\text{H}_3$ $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}^+\text{H}_3$	<i>trans</i> -3-Cyanomethyl-2-phenylcyclohexan-1-one (86) 2-Phenyl-3-nitromethylcyclohexan-1-one (80) Methyl <i>trans</i> -2-phenylcyclohexan-1-one-3-nitroacetate (90)	108 106, 668 106, 668
6-Phenyl-2-cyclohexen-1-one and Dibenzyl malonate ††	KOC_4H_9 <i>t</i>	<i>trans</i> -6-Phenylcyclohexanone-3-acetic acid ††	107
4-Phenyl-2-cyclohexen-1-one and Dibenzyl malonate ††	KOC_4H_9 <i>t</i>	<i>trans</i> -4-Phenylcyclohexanone-3-acetic acid ††	107
Cyclohexylidenecyclohexanone and Cyanoacetamide	NaOC_2H_5	Compound $\text{C}_{15}\text{H}_{20}\text{N}_2\text{O}$	670
1-Butyryl-2,6-dimethylcyclohexene and Diethyl malonate	NaOC_2H_5	<i>trans</i> (?) 2-Ethyl-8,10-dimethyldecalin-1,3-dione	96

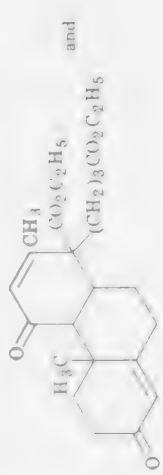
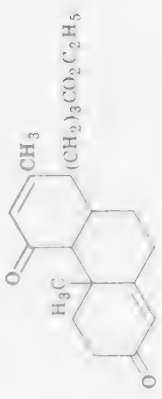

Note: References 491–1045 are on pp. 545–555.

†† A mixture of 4- and 6-phenyl-2-cyclohexen-1-one was used in this experiment.

‡‡ The product was obtained after hydrolysis and partial decarboxylation.

TABLE VII—Continued
MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES

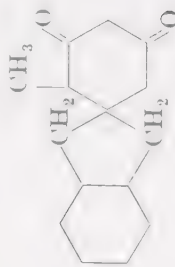
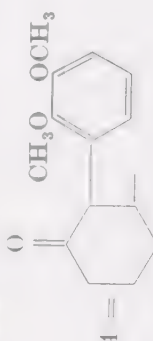
Reactants	Catalyst	Product (Yield, %)	References
2-Hydrindanylideneacetone and Diethyl malonate	NaOC_2H_5	 (90)	222
Cyanoacetamide	NaOC_2H_5	 NH (Quant.)	49
1,10-Dimethyl-2-oxo-2,3,4,5,6,10-hexahydronaphthalene and Diethyl malonate	NaOC_2H_5	 (67)	671
Diethyl methylmalonate	—	 (67)	672

1-Benzocyclohexene and ethylmethyl malonate	KOC^tH_9	<i>trans</i> -2-Benzocyclohexylmalonic acid (64)	667
2-Phenyl-2-cyclohepten-1-one and ethylmethyl malonate	KOC^tH_9	Dibenzyl 2-phenylcycloheptan-1-one-3-malonate (90)	108
1-Acetyl-9-methyl-6-oxo-3,4,6,7,8,9-hexahydronaphthalene and Diethyl α -acetyl adipate	Na	 and	663
1-Acetyl-6-methoxy-3,4-dihydronaphthalene and Ethyl acetate	NaOC^tH_5		673
Cyclohexane-1,2-dione	—		674

Note: References 491–1045 are on pp. 545–555.

11 The product was obtained after hydrolysis and partial decarboxylation.

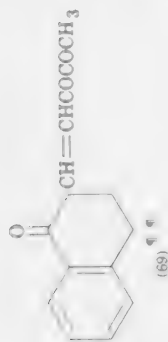
TABLE VII—Continued

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL (CYCLO)ALKENES			References
Reactants	Catalyst	Product (Yield, %)	
<i>Methyl α-Hydrindanylideneethyl Ketone and</i>			
Diethyl malonate	Na		223
<i>2-Hydroxymethylenecyclododecanone and</i>			
Diethyl acetone-1,3-dicarboxylate	NaOC_2H_5		428
<i>2-(2,3-Dimethoxyphenyl)-2-cyclohexen-1-one and</i>			
Dimethyl malonate	NaOCH_3	$\text{ACH}(\text{CO}_2\text{CH}_3)_2$ (97)	106, 668
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (94)	106, 668
Dibenzyl malonate	KOC_4H_9 - <i>t</i>	$\text{ACH}(\text{CO}_2\text{CH}_2\text{C}_6\text{H}_5)_2$ (88)	108, 669
Methyl cyanoacetate	NaOCH_3	$\text{ACH}(\text{CN})\text{CO}_2\text{CH}_3$ (95)	106, 668
Ethyl cyanoacetate	NaOC_2H_5	$\text{ACH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (90)	106, 668
Benzyl cyanoacetate	KOC_4H_9 - <i>t</i>	ACH_2CN (82)§§	108, 669
Methyl nitroacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OCH}_3$	$\text{ACH}(\text{NO}_2)\text{CO}_2\text{CH}_3$ (90)	106, 668
<i>1-Benzoylcycloheptene and</i>			
Dibenzyl malonate	KOC_4H_9 - <i>t</i>	<i>trans</i> (?)-2-Benzoylcycloheptylmalonic acid (46)	667

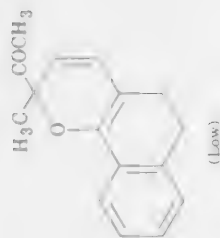
2-Isopropoxymethylene-1-tetralone and

Biacetyl monodimethyl ketal

Na



and



675

2-(2',3',4'-Trimethoxyphenyl)-2-cyclohepten-1-one and

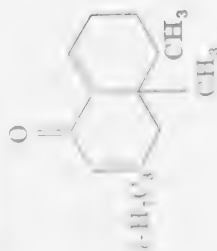
Dioctyl malonate

 $\text{KOC}_4\text{H}_9\text{t}$

676

3-Oxo-2-(2',3',4'-trimethoxyphenyl)cycloheptan-1-acetic acid (72) $\ddagger\ddagger$

Zerumbone



and

Ethyl cyanoacetate


—

Compound $\text{C}_{25}\text{H}_{36}\text{N}_2\text{O}_5$

677

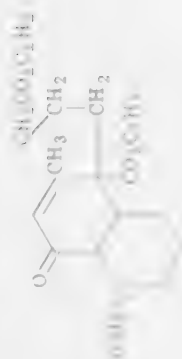
Note: References 491–1045 are on pp. 545–555. \equiv The product was obtained after hydrolysis and partial decarboxylation. \equiv This product was obtained after partial hydrolysis and decarboxylation. \equiv The product was obtained after hydrolysis. \equiv This product results from spontaneous dehydrogenation or disproportionation of the expected compound.

TABLE VII—Continued

MICHAEL CONDENSATIONS WITH CYCLOALKENONES AND ACYL CYCLOALKENES			
Reactants	Catalyst	Product (Yield, %)	References
2-Isopropoxymethylenbenzosuberone and Ethoxycarbonylmethyl ketol	Na	 (35) ¹⁴	675
2-Cyclopentadecen-1-one and Diethyl malonate	NaOC ₂ H ₅		532
2-Hydroxymethylenecyclopentadecanone and Diethyl acetate-1,3-dicarboxylate	NaOC ₂ H ₅		428
2-Hydroxymethylenecyclohexadecanone and Diethyl acetate-1,3-dicarboxylate	NaOC ₂ H ₅		428

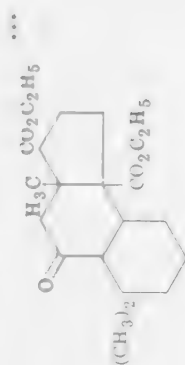
3,5-Cholestadien-7-one and

4-oxocyclohexanone

 $\text{NaO}_2\text{C}_2\text{H}_5$; piperidine

Diethyl 7-oxo-5-cholestene-3-malonate (50)

648

 $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)\text{MgBr}$ 

663

Note: References 491–1045 are on pp. 545–555.

** This product results from spontaneous dehydrogenation or disproportionation of the expected compound.


*** This reaction takes place when

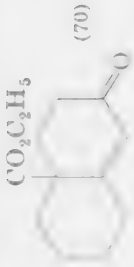



is treated with the reagent or when 1-acetyl-6,6-dimethyl-4-cyclohexene is condensed with ethyl α -acetyladipate in the presence of sodium amide.

TABLE VIII

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES





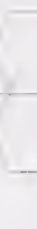
Substituent R in $\text{CH}_3\text{OOCCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %)	References
			$A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	
$(\text{C}_6\text{H}_5)_2\text{N}$	$\text{CH}_2(\text{CO}_2\text{C}_2\text{H}_5)_2$	NaOC_2H_5	$A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	679
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_2\text{I}$	$\text{C}_6\text{H}_5\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	NaNH_2	$\text{C}_6\text{H}_5\text{C}(A)(\text{CO}_2\text{C}_2\text{H}_5)_2$	680
$(\text{CH}_3)_2\text{N}$	$\text{CH}_3\text{COCH}_2\text{CO}_2\text{C}_2\text{H}_5$	NaOC_2H_5	4-Carbethoxy-3-methyl-2-cyclohexen-1-one	629, 681
$(\text{CH}_3)_2\text{N} \cdot \text{CH}_3\text{I}$	$\text{CH}_3\text{COCH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$	—	3,6-Dimethyl-2-cyclohexen-1-one	682
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$	$\text{CH}_3\text{COCH}(\text{CH}_2\text{C}_6\text{H}_5)(\text{CO}_2\text{C}_2\text{H}_5)$	—	6-Benzyl-3-methyl-2-cyclohexen-1-one	683
	Ethyl isobutyrylacetate	NaOC_2H_5	Ethyl 2-isobutyryl-5-oxohexanoate (65)	684
$\begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{C} \end{array}$	Ethyl α -acetylisovalerate	NaOC_2H_5	6-Isopropyl-3-methyl-2-cyclohexen-1-one* (50)	100
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$	Diethyl α -methylloxalacetate	NaOC_2H_5	Ethyl 1-methyl-2,4-dioxocyclohexane-1-pyruvate	685
	Dimethyl α -methyl- β -oxoadipate	NaOCH_3 , pyridine		686
$(\text{C}_4\text{H}_9)_2\text{N}$	2-Carbethoxycyclohexan-1-one	NaOC_2H_5 , pyridine	2-(β -Acetyl-ethyl)-2-carbethoxycyclohexan-1-one	230

$(C_2H_5)_3N/CH_3I$	2-Carbomethoxycyclohexan-1-one	$NaOC_2H_5$		68, 229
	2-Carbomethoxycycloheptan-1-one	$NaOCH_3$		688
	2-Carbomethoxycyclooctan-1-one	$NaOCH_3$		689, 690
	2-Carbomethoxycyclononan-1-one	$NaOCH_3$		689, 690
	2-Carbomethoxycyclodecan-1-one	$NaOCH_3$		688
	Methyl 1-oxo-1,2,3,4-tetrahydro-phenanthrene-2-carboxylate	$NaOCH_3$		485

Note: References 491-1045 are on pp. 545-555.

* This product, piperitone, results from hydrolysis and decarboxylation.


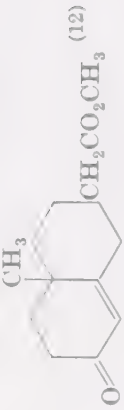


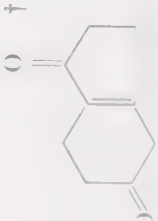
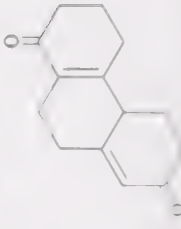
TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES					
Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %) $A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	References	
	Methyl 1-oxo-1,2,3,4-tetrahydro-phenanthrene-2-carboxylate	NaOCH_3	 (98)	532	
	Methyl 4-oxo-1,2,3,4-tetrahydro-phenanthrene-3-carboxylate	NaOCH_3	 (92)	533	
$(\text{C}_6\text{H}_5)_2\text{N}$	$\text{C}_6\text{H}_5\text{COCH}_2$	None	3-Methyl-2-cyclohexen-1-one (16)	691	
	Cyclopentanone	None	 (28)	691	
$(\text{C}_6\text{H}_5)_2\text{N}-\text{C}(\text{CH}_3)=\text{CH}_2$	2-Methylcyclopentanone	NaNH_2 NaOC_2H_5		229, 230	

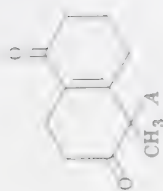
9-Methylcyclohexanone		NaNH_2	229, 687
2-Formylcyclohexanone		$\text{KOC}_4\text{H}_9\text{-}t$	687
2-Formylcyclohexanone		$(\text{C}_6\text{H}_5)_3\text{CNa}$	692
2-Formylcyclohexanone		KOH, ethanol	693
2-Formylcyclohexanone		NaOCH_3	664, 190
2-Formylcyclohexanone		NaOCH_3	694

Note: References 491-1045 are on pp. 545-555.

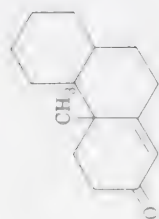
TABLE VIII—Continued

Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %) $A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	References
$(\text{C}_6\text{H}_5)_2\text{N}-\text{CH}_2-$ (<i>Cont.</i>)	5-Carbomethoxymethyl-2-methyl- cyclohexan-1-one	NaOCH_3		664
		NaNH_2		664
	2-Acetyl-3,3-dimethylcyclohexane- 1-one	NaOCH_3		695
	<i>trans</i> -2-Decalone	NaNH_2		229
		NaOCH_3		537

537

NaOCH₃

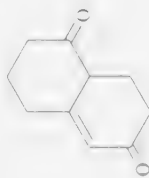
696

NaNH₂

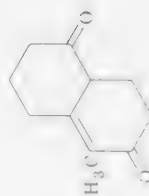
1-Methyl-2-decalone

Note: References 491-1045 are on pp. 545-555.

† The compound actually employed was the isomer of the structure


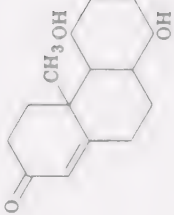
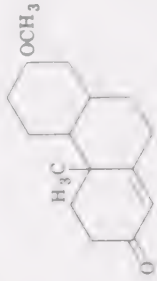
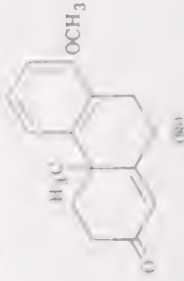


+ A mixture of this compound with the isomer of the structure

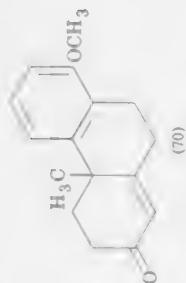


was used. Part of the material was dehydrogenated to 6-hydroxy-5-methyl-1-tetralone.

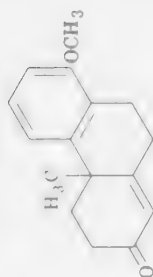
TABLE VIII—Continued

Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %)	References
$(\text{C}_6\text{H}_5)_2\text{N}-\text{CH}_3$ (Cont.)	10-Methyl-2-decalone	NaNH_2		230
	1,4-Dihydroxy-8-methyl-7-decalone	$[(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}]$		540
$(\text{CH}_3)_2\text{N}$	2-Phenylcyclohexanone	NaNH_2	2-Oxo-10-phenyl-2,3,4,5,6,7,8,10-octahydronaphthalene (42)	113
$(\text{C}_6\text{H}_5)_2\text{N}-\text{CH}_3$	1-Methyl-6-methoxy-2-decalone	NaNH_2		692
	1-Methyl-5-methoxy-2-tetralone	NaNH_2		698

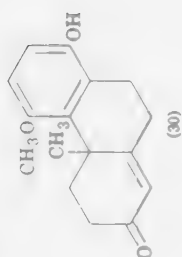
318



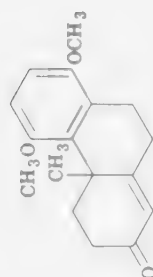
693



693



699

KOC₂H₅

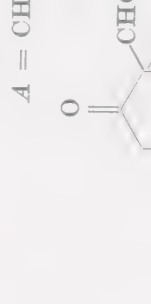
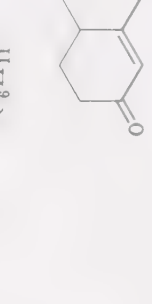
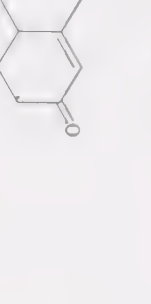
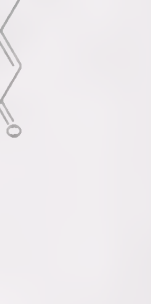
KOH, ethanol


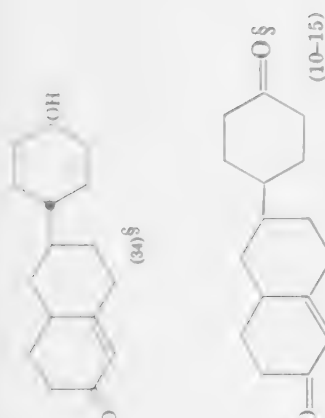
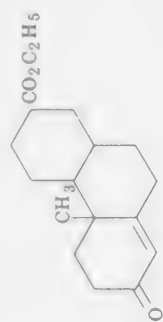

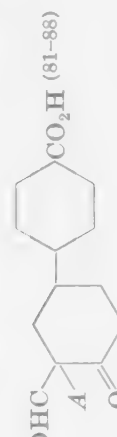
5-Hydroxy-1-methyl-8-methoxy-2-tetralone

5,8-Dimethoxy-1-methyl-2-tetralone NaNH₂

Note: References 491-1045 are on pp. 545-555.

TABLE VIII—Continued

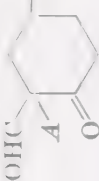


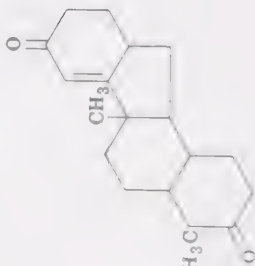
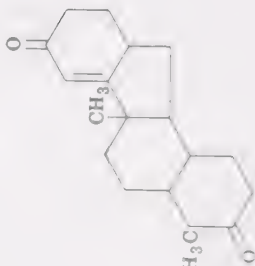
Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Robinson's Modification of the Michael Condensation of α,β -Ethylene Ketones	Addend	Catalyst	Product (Yield, %)	References
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$ (<i>Cont.</i>)		1-Cyclohexyl-2-hydroxymethylene- cyclohexan-1-one	NaOCH_3	$\text{A} = \text{CH}_3\text{COCH}_2\text{CH}_2\text{---}$  (76) and (21) C_6H_{11}	700
		2-Hydroxymethylene-4-(<i>trans</i> -4'- hydroxycyclohexyl)cyclohexan- 1-one	NaOCH_3	 (35)§	532
$(\text{C}_2\text{H}_5)_2\text{N}$		2-Hydroxymethylene-4-(<i>trans</i> -4'- hydroxycyclohexyl)cyclohexan- 1-one	NaOCH_3	 (29)§	692
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$		2-Hydroxymethylene-4-(<i>cis</i> -4'-oxo- cyclohexyl)cyclohexan-1-one	NaOCH_3	 (40)§	532

$(C_6H_5)_2N$	2-Hydroxymethylene-4- <i>vers</i> -4'-oxo-cyclohexylcyclohexan-1-one	$NaOCH_3$		692
$(C_6H_5)_2N$	2-Hydroxymethylene-4-(1'-oxo-cyclohexyl)cyclohexan-1-one	$NaOCH_3$		532, 692
$(C_6H_5)_2N$	6-Carboethoxy-1-methyl-2-decalone	$NaNH_2$		697
$(C_6H_5)_2N$	7,8-Dimethoxy-1-ethyl-2-tetralone	$NaNH_2$		701
$(C_6H_5)_2N$	2-Hydroxymethylene-4-(1'-carboxy-cyclohexyl)cyclohexan-1-one	$NaOCH_3$		702

Note: References 491-1045 are on pp. 545-555.

§ This product resulted from the cyclization of the primary product, which has not been isolated.

TABLE VIII—Continued
ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %)	References
$(\text{CH}_3)_3\text{N} \cdot \text{I}$ (Cont.)	2-Hydroxymethylene-4-(4'-carboxy-phenyl)cyclohexan-1-one	NaOCH_3	$A = \text{CH}_3\text{COCH}_2\text{CH}_2---$ 	702
	2-Hydroxymethylene-4-(4'-carbo-methoxycyclohexyl)cyclohexan-1-one	NaOCH_3		702
	2-Hydroxymethylene-4-(1'-carbo-methoxyphenyl)cyclohexan-1-one	NaOCH_3		702
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$		NaNH_3		703

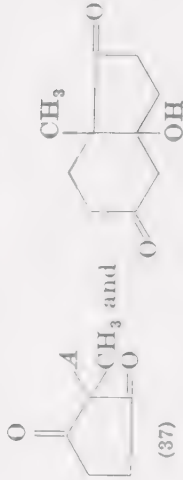
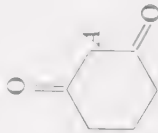
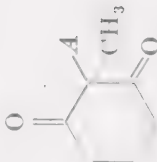
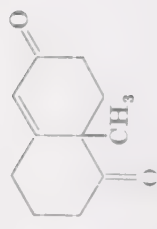
(Mixture of isomers)

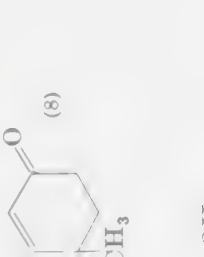

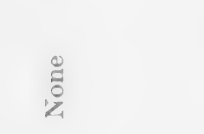

	NaNH_2		704
	NaOCH_3		532
	NaOCH_3		533
	NaOC_2H_5		705
	NaOCH_3		694

Note: References 491–1045 are on pp. 545–555.

|| This is the structure assumed by the authors.

TABLE VIII—*Continued*
ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

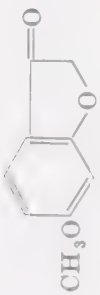
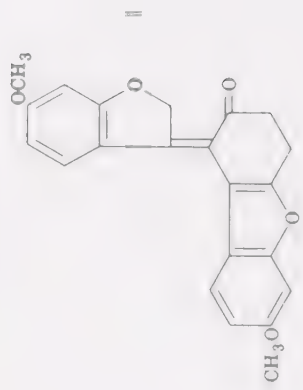


Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %) $A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	References
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$ (<i>cont.</i>)	2-Methylcyclopentane-1,3-dione	NaOCH_3	 (37)	528, 706
	Cyclohexane-1,3-dione	Piperidine		532
	2-Methylcyclohexane-1,3-dione	None		663
		NaOCH_3 ; NaNH_2 ; $(\text{C}_2\text{H}_5)_2\text{NH}$; pyridine; NaOC_2H_5	 ()	663, 706, 707

$(C_2H_5)_2N$	2-Methylcyclohexane-1,3-dione	None	 $NaOC_2H_5$ and CH_3	528
$(C_2H_5)_2N$	2-Methylcyclohexane-1,3-dione	None	 None	538
$(C_2H_5)_2N \cdot CCl_3I$	2-Methylcyclohexane-1,3-dione	$NaOCH_3$	 OH	708, 709
$(C_2H_5)_2N$	5,5-Dimethylcyclohexane-1,3-dione	None	 $(CH_3)_2$	538
$(CH_3)_2N$ $(C_2H_5)_2N$	Nitromethane 2-Nitropropane	$NaOC_2H_5$ $NaOH$	ACH_2NO_2 $(CH_3)_2C(A)NO_2$ (85)	710 691

Note: References 491-1045 are on pp. 545-555.

* This compound is formed by ring fission of the primary product.

TABLE VIII—Continued
ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Substituent R in $\text{CH}_3\text{COCH}_2\text{CH}_2\text{R}$	Addend	Catalyst	Product (Yield, %) $A = \text{CH}_3\text{COCH}_2\text{CH}_2-$	References
$(\text{C}_2\text{H}_5)_2\text{N} \cdot \text{CH}_3\text{I}$		NaNH_2		711
 $\text{N} \cdot \text{CH}_3\text{I}$	Methyl fluorene-9-carboxylate	KOH	Methyl 9-(β -acetyloxyethyl)fluorene-9-carboxylate (45)	544
 $\text{NCH}_3 \cdot \text{CH}_3\text{I}$ and Diethyl malonate Diethyl acetoacetate			$A = (\text{CH}_3)_2\text{NCH}_2\text{CH}_2\text{COCH}_2\text{CH}_2-$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (25) $(\text{CH}_3\text{COCH}_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$	681 681

681

 KOC_2H_5

2-Carbethoxycyclopentanone

681

 KOC_2H_5

2-Carbethoxycyclohexanone

 $A = \text{CH}_3\text{SCH}_2\text{CH}_2\text{COCH}_2\text{CH}_2-$

712

 $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (42) KOC_2H_5

Diethyl malonate

712

 $(\text{CH}_3\text{O}_2\text{C}(\text{CH}_2)_2\text{OOC}(\text{A})(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5)$ (70) KOCH_3 Dimethyl β -keto- α -methyladipate

712

 KOC_2H_5

2-Carbethoxycyclopentanone

712






 $(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (41) KOC_2H_5

2-Nitropropane

Note: References 491–1045 are on pp. 545–555.

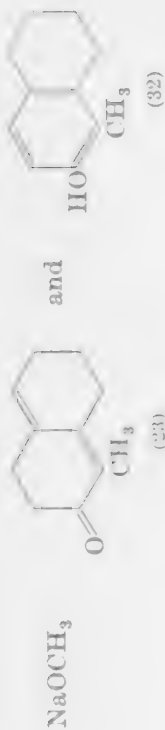
|| This is the structure assumed by the authors.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES	Reactants	Catalyst	Product (Yield, %)	References
	$CH_3CH_2COCH_2CH_2N(C_2H_5)_2 \cdot CH_3I$ and 2 Carbethoxycyclohexanone**	$NaOC_2H_5$		231
	Methyl 1-oxo-1,2,3,4-tetrahydronaphthene-2-carboxylate	$NaOCH_3$	Methyl 1-oxo-2-(β -propionylethyl)-1,2,3,4-tetrahydronaphthene-2-carboxylate (96)	532
	Methyl 4-oxo-1,2,3,4-tetrahydronaphthene-3-carboxylate	$NaOCH_3$	Methyl 4-oxo-3-(β -propionylethyl)-1,2,3,4-tetrahydronaphthene-3-carboxylate (87)	533
	Cyclohexane-1,3-dione	$(C_2H_5)_3N$		115, 532
	2-Hydroxycyclohexanone	None		713
	2-Methylcyclohexanone	$NaNH_2$	 and 	714

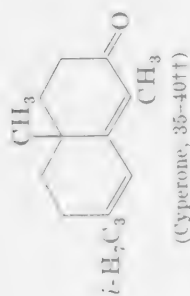
2 Acetoxycyclohexanone

713



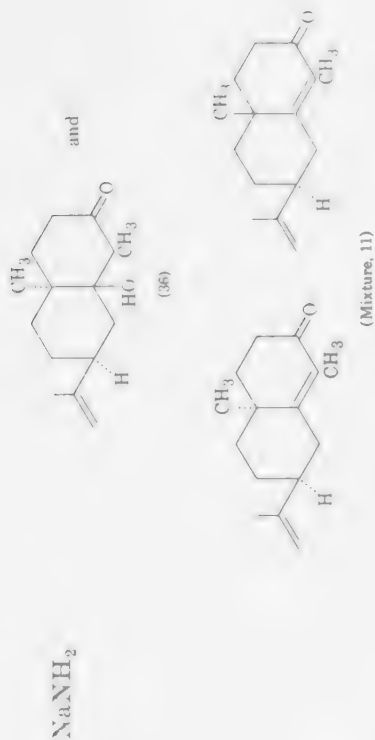
Carvenone

715



(+) - Dihydrocarvone

716



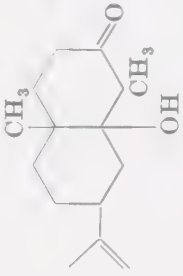
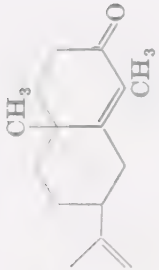
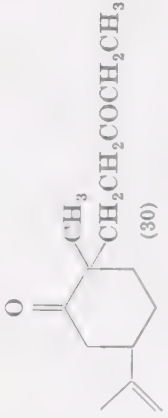
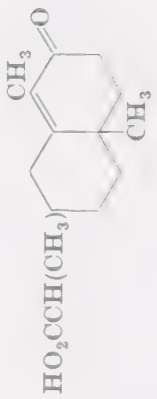
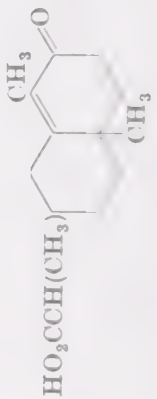
Note: References 491-1045* are on pp. 545-555.




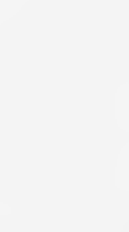

** In this instance, the tertiary base was used instead of the quaternary methiodide.

†† This compound resulted from the treatment of the crude primary product with boiling potassium hydroxide solution.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
$CH_3CH_2COCH_2CH_2N(C_2H_5)_2 \cdot CH_3I$ (Cont.) and (-)-Dihydrocarvone	$NaNH_2$	 and 	714
		 (30)	717
5 (2-Carbomethoxyethyl)-2-methylcyclohexanone	$NaOCH_3$	 (15††, 70§§)	664, 718
	$NaNH_2$	 (45, 10)	188, 718

187	$(C_6H_5)_3CNa$		187
230	$NaNH_2$		230
684	—		684
100	$NaOC_2H_5$		100
720	$NaOC_2H_5$		720

Note: References 491–1045 are on pp. 545–555.

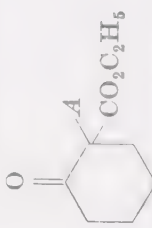
††† This compound resulted from the treatment of the crude primary product with boiling potassium hydroxide solution.

++ About two-thirds of the keto ester failed to enter into the reaction.

§§ One-quarter of the keto ester could be recovered unchanged.

The ester obtained in the reaction was hydrolyzed.

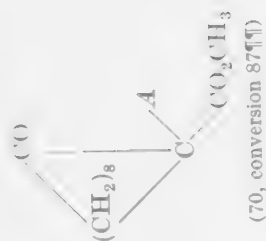
TABLE VIII—Continued
ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
$CH_3COCH[CH_2N(CH_{3/2} \cdot C_2H_5I)_2]$ and $CH_3COCH[CH_2N(CH_{3/2} \cdot C_2H_5I)_2]$ and		$A = CH_3COCCH_2-$ 	689
2-Carboethoxycyclohexanone	$NaOCH_3$	(74, conversion 65%)	
2-Carboethoxycycloheptanone	$NaOCH_3$	(67)	689
2-Carboethoxycyclooctanone	$NaOCH_3$	(66, conversion 89%)	689

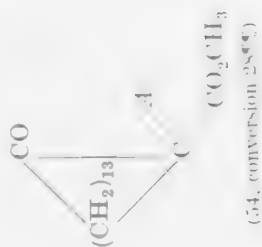
689

NaOCH₃

689

NaOCH₃

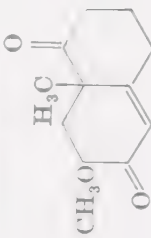
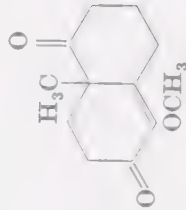
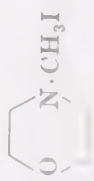


688

NaOCH₃

Note: References 491-1045 are on pp. 545-555.

Only the indicated amount of the keto ester entered into the reaction; the balance could be recovered unchanged.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES			
Reactants	Catalyst	Product (Yield, %)	References
$CH_3OCH_2COCH_2CH_2N(C_2H_5)_2$ and $CH_3COCH(OCH_3)(C_2H_5)_2$ (mixture) and 2-Methylcyclohexanone-1,3-dione	Pyridine	 and 	721
Substituent R in $(CH_3)_2CHCOCH_2CH_2R$	Addend	Product (Yield, %)	References
CH_3N	Ethyl acetoacetate	—	722
	Ethyl methylacetoacetate	Carvenone (43)	100
Reactants	Catalyst	Product (Yield, %)	References
$(CH_3)_2CHCH_2COCH_2CH_2N$  $\dot{O} \cdot CH_3I$ and Ethyl acetoacetate	$NaOC_2H_5$	3-Isobutyl-2-cyclohexen-1-one (45)	100
$(CH_3)_3CCOCH_2CH_2N$  $\dot{O} \cdot CH_3I$ and Ethyl acetoacetate	$NaOC_2H_5$	3-4-Butyl-2-cyclohexen-1-one (45)	100

2-Diethylaminomethyl-5-methylcyclopentanone methiodide and

Ethyl acetoacetate

 NaOC_2H_5 

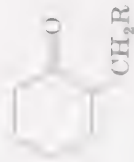
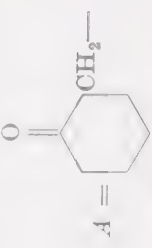
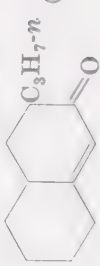

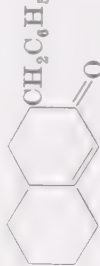
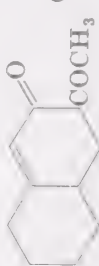

229

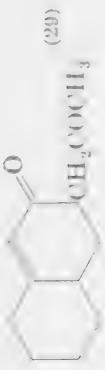
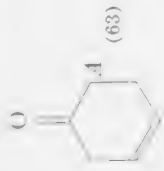

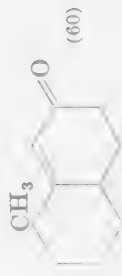
Substituent R in	Addend	Catalyst	Product (Yield, %)	References
 $(\text{CH}_3)_2\text{N}$ $(\text{CH}_3)_3\text{N} \cdot \text{CH}_3\text{I}$	Diethyl malonate Diethyl malonate	NaOC_2H_5 NaOC_2H_5	 $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (60-66) $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (60-66)	114, 723 114, 723
$(\text{CH}_3)_2\text{N}$	Ethyl acetoacetate	NaOC_2H_5	 (70)	724
$(\text{CH}_3)_2\text{N} \cdot \text{CH}_3\text{I}$	Ethyl methylacetoacetate	NaOC_2H_5 ; NaOC_3H_7 - <i>i</i>	 (40-55)	725
	Ethyl ethylacetoacetate	NaOC_2H_5 ; NaOC_3H_7 - <i>i</i>	 (35-40)	725

Note: References 491-1045 are on pp. 545-555.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

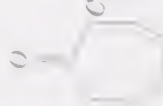
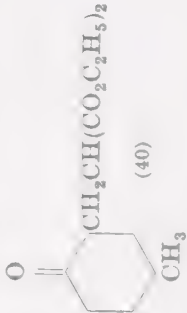
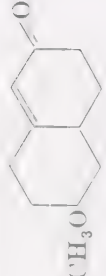
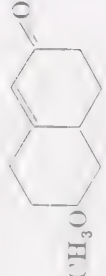
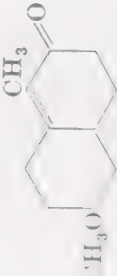
Substituent R in	Addend	Catalyst	Product (Yield, %)	References
				
$(\text{CH}_3)_2\text{N}\cdot\text{CH}_2\text{I}$ (<i>Cont.</i>)	Ethyl <i>n</i> -propylacetate	NaOC_2H_5	 $\text{C}_3\text{H}_7\text{-}n$ (30-35)	725
	Ethyl allylacetate	NaOC_2H_5	 $\text{CH}_2\text{CH}=\text{CH}_2$ (20)	726
	Ethyl phenylacetate	NaOC_2H_5	$\text{CH}_3\text{COC}(A)(\text{C}_6\text{H}_5)\text{CO}_2\text{C}_2\text{H}_5$	725
	Ethyl benzylacetate	NaOC_2H_5	 $\text{CH}_2\text{C}_6\text{H}_5$ (35-40)	725
Acetylacetone		None	 (60)	691
$(\text{CH}_3)_2\text{N}$	Cyclopentanone	None	 (73)	691

Hexane-2,5-dione	None		(29)	691
Cyclohexanone	None		(63)	691
Nitromethane	NaOC_2H_5	AClH_2NO_2		710
Nitroethane	NaOC_2H_5	$\text{AClH}(\text{CH}_3)\text{NO}_2$		726
1-Nitropropane	NaOH	$\text{ACH}(\text{C}_2\text{H}_5)\text{NO}_2$ (78)		691
2-Nitropropane	NaOH	$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (81)		691
				References
Diethyl malonate	NaOC_2H_5		(42)	114
Ethyl acetoacetate	NaOC_2H_5		(60)	229

Note: References 491-1045 are on pp. 545-555.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
2-Diethylaminomethyl-4-methylcyclohexanone Methiodide and 			
Diethyl malonate	NaOC_2H_5	 (40)	114
2-Diethylaminomethyl-4-methoxycyclohexanone Methiodide and 			
Ethyl acetoacetate	NaOC_2H_5	 (28)	697
Ethyl β -oxovalerate	NaOC_2H_5	 (28)	697
Diethyl malonate	NaOC_2H_5	Diethyl 2-(2'-oxocycloheptyl)octane-1,1-dicarboxylate	727

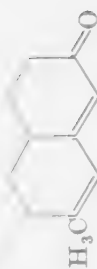
727, 728

NaOC₂H₅

Ethyl acetate

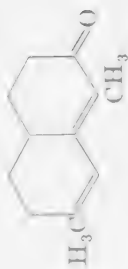
5-Dimethylaminomethyl-3-methyl-2-cyclohexen-1-one Methiodide and

682



Ethyl acetate

682



Ethyl propionylacetate

Ethyl 7-piperidino-5-oxoheptanoate and

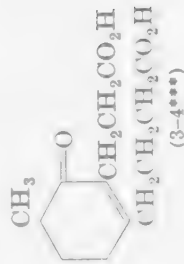
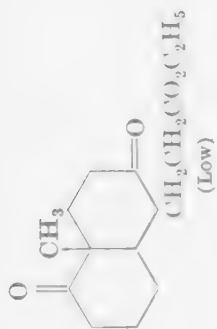


2-Methylcyclohexane-1,3-dione

Pyridine

(50-55)

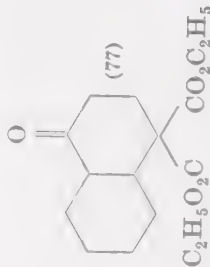
708

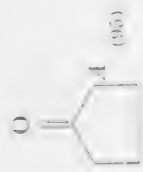


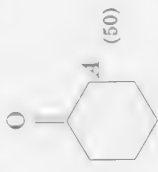
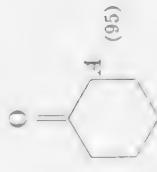

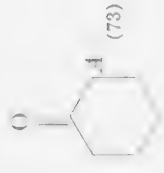


Note: References 491-1045 are on pp. 545-555.

*** This compound is formed by ring fission of the primary product and recyclization. When the methiodide of ethyl 7-piperidino-5-oxoheptanoate was employed in conjunction with sodium methoxide, the dibasic acid was the main product of the reaction.




TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENE KETONES			References
Reactants	Catalyst	Product (Yield, %)	
β -Dimethylaminoethyl Cyclohexyl Ketone Hydrochloride and Methyl acetoacetate	KOC_4H_9	3-Cyclohexyl-2-cyclohexen-1-one (30)	729
4-(β -Dimethylaminopropionyl)-1-cyclohexene Hydrochloride and Methyl acetoacetate	KOC_4H_9	4-Acetyl-4-carbomethoxy-1-decalone (17)	729
1-(β -Morpholinopropionyl)-1-cyclohexene Methiodide and Diethyl malonate	NaOC_2H_5		100
Substituent R in $\text{RCH}_2\text{CH}_2\text{COC}_6\text{H}_5$	Addend	Catalyst	Product (Yield, %)
$(\text{CH}_3)_2\text{N} \cdot \text{HCl}$	Methyl acetoacetate	KOC_4H_9	$\text{A} = -\text{CH}_2\text{CH}_2\text{COC}_6\text{H}_5$
$(\text{CH}_3)_2\text{N}$	Ethyl acetoacetate	KOC_4H_9	3-Phenyl-2-cyclohexen-1-one (60)
	Ethyl acetoacetate	NaOC_2H_5	3-Phenyl-2-cyclohexen-1-one (60)
	Ethyl acetoacetate	NaOC_2H_5	6-Carbethoxy-3-phenyl-2-cyclohexen-1-one
	Ethyl acetoacetate	NaOC_2H_5	3-Phenyl-2-cyclohexen-1-one (60)

$\alpha\text{H}_4\text{N}$	Cyclopentanone	None		691
	Cyclopentanone	None		691
$\alpha\text{H}_4\text{N}$	Acetylacetone	None	6-Acetyl-3-phenyl-2-cyclohexen-1-one (50)	691
	Cyclohexanone	$\text{NaOH}, \text{C}_2\text{H}_5\text{OH}$		731
		None		691
	Cyclohexanone	None		691

Note: References 491-1045 are on pp. 545-555.

TABLE VIII—Continued
ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

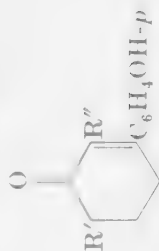
Substituent R in $RCH_2CH_2COC_6H_5$	Addend	Catalyst	Product (Yield, %)	References
$(CH_3)_2N$	Hexane-2,5-dione	None	$A = -CH_2CH_2COC_6H_5$ 6-Acetyl-3-phenyl-2-cyclohexen-1-one (22) $ACH_2COC_6H_5$ (40) $C_6H_5CH(A)COC_6H_5$ (9) ACH_2NO_2 , $(A)_2CHNO_2$, $(A)_3CNO_2$ ACH_2NO_2 (13) ACH_2NO_2 (15) $ACH(CH_3)NO_2$ (7) and $A_2C(CH_3)NO_2$ (50)	691
	Acetophenone	None		691
	Deoxybenzoin	None		691
	Nitromethane	$NaOC_2H_5$ NaOH		710 691
	Nitroethane	None NaOH		691 691
$(CH_3)_2N$ 	Nitroethane	NaOH	$A_2C(CH_3)NO_2$ (30)	691
	1-Nitropropane	$NaOC_2H_5$	$ACH(CH_3)NO_2$ (48) and $A_2C(CH_3)NO_2$ (30)	691
	1-Nitropropane	NaOH	$ACH(C_2H_5)NO_2$ (80)	691
$(CH_3)_2N$ 	2-Nitropropane	$NaOC_2H_5$ NaOH	$ACH(C_2H_5)NO_2$ (60) $(CH_3)_2C(A)NO_2$ (12)	691 691
	2-Nitropropane	NaOH	$(CH_3)_2C(A)NO_2$ (84)	691
$(CH_3)_2N$ 	1-Nitro-2-phenylethane	NaOH	$C_6H_5CH_2CH(A)NO_2$ (68) and $(C_6H_5CH_2CH(A))_2NO_2$ (7)	691



544

References

Product (Yield, %)

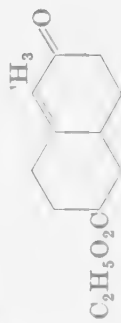


R' = R'' = H (30) 729
 R' = C₂H₅, R'' = H (71) 729
 R' = (CH₃)₂CH and (O₂C)₂H₅, R'' = H (30) 729
 R' = R'' = CH₃ (56) 729
 R' = R'' = C₆H₅ (15) 729
 R' = CH₃CO, R'' = H (12) 729

p-Dimethylamino-*p*-hydroxypropionophenone Hydrochloride and

Ethyl acetoacetate KOC₄H₉-*t*
 Ethyl ethylacetoacetate KOC₄H₉-*t*
 Ethyl isopropylacetoacetate KOC₄H₉-*t*
 Ethyl α-propionylpropionate KOC₄H₉-*t*
 Ethyl α,γ-diphenylacetoacetate KOC₄H₉-*t*
 Acetylacetone KOC₄H₉-*t*

4-Carboethoxy-2-diethylaminomethylcyclohexanone Methiodide and



697

Ethyl β-oxovalerate

NaOC₂H₅

2-Morpholinomethyl-1-hydrindone Methiodide and



732


Ethyl acetoacetate

NaOC₂H₅

Note: References 491-1045 are on pp. 545-555.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
<i>p</i> -Dimethylaminomethyl <i>p</i> -Methoxyphenyl Ketone Hydrochloride and			
Ethyl acetoacetate	KOC ₄ H ₉ - <i>t</i>	R = H (40)	729
Ethyl ethylacetoacetate	KOC ₄ H ₉ - <i>t</i>	R = C ₂ H ₅ (64)	729
Ethyl isopropylacetoacetate	KOC ₄ H ₉ - <i>t</i>	R = (CH ₃) ₂ CH (30)	729
Acetylacetone	KOC ₄ H ₉ - <i>t</i>	R = CH ₃ CO (36)	729
Nitroethane †††	KOC ₄ H ₉ - <i>t</i>	<i>p</i> -Methoxy- <i>o</i> -nitrobutyrophenone	710
<i>p</i> -Dimethylaminoisopropyl Phenyl Ketone Hydrochloride and			
Ethyl acetoacetate	KOC ₄ H ₉ - <i>t</i>	4-Methyl-3-phenyl-2-cyclohexen-1-one (40, 38)	729, 730
β -Morpholino- α -phenylethyl Methyl Ketone and			
2-Nitropropane	NaOH	2-Methyl-2-nitro-4-phenylhexan-5-one (89)	691
<i>o</i> -Isopropyl-3-methyl-2-morpholinomethylcyclohexan-1-one Methiodide and			
Ethyl acetoacetate	NaOC ₂ H ₅		733

2-Dimethylaminomethyl-1-tetralone and

Ethyl acetoacetate	NaOC ₂ H ₅	R = H	724
Ethyl methylacetoacetate	NaOC ₂ H ₅	R = CH ₃	724

p-Methylamino- α -(*p*-methoxyphenyl)ethyl Methyl Ketone Methiodide and

2-Hydroxymethylene-6-methoxy-1-tetralone	NaOC ₂ H ₅	2-(<i>p</i> -Methoxyphenyl)-3-oxo-7-methoxy-1,2,3,9,10,10a-hexahydrophenanthrene (46)	734
--	----------------------------------	--	-----

3,4-Dimethoxyphenyl β -Dimethylaminoethyl Ketone and

Nitromethane	NaOC ₂ H ₅	1-(3',4'-Dimethoxyphenyl)-4-nitrobutan-1-one	710
--------------	----------------------------------	--	-----

p-Dimethylamino- β -(*p*-methoxyphenyl)ethyl Methyl Ketone and

Nitromethane	NaOC ₂ H ₅	4-(<i>p</i> -Methoxyphenyl)-5-nitropentan-2-one	710
--------------	----------------------------------	--	-----

p-Dimethylamino- β -(3,4-dimethoxyphenyl)ethyl Methyl Ketone and

Nitromethane	NaOC ₂ H ₅	4-(3',4'-Dimethoxyphenyl)-5-nitropentan-2-one	710
--------------	----------------------------------	---	-----

Note: References 491-1045 are on pp. 545-555.

††† The free base was employed, instead of the hydrochloride.

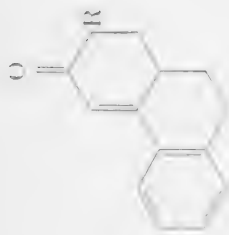


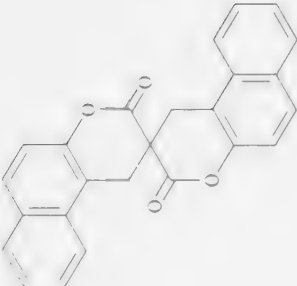
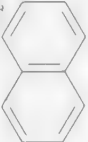
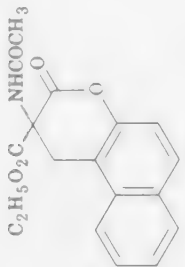


TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES

Reactants	Catalyst	Product (Yield, %)	References
β -Dimethylamino- β -(3,4-methylenedioxyphenyl)ethyl Methyl Ketone and Nitromethane	NaOC_2H_5	4-(3',4'-Methylenedioxyphenyl)-5-nitropentan-2-one	710
2-Dimethylaminomethylbenzosuberone and Diacetyl monoo dimethyl ketal	Na enolate		394
β -Dimethylaminoethyl 6-Methoxy-2-naphthyl Ketone Hydrochloride and Methyl methacrylate	$\text{KOH}, (\text{C}_2\text{H}_5)_2\text{CHOH}$	3-(6'-Methoxy-2'-naphthyl)cyclohexen-1-one (70)	735
β -Dimethylamino- β -phenylethyl 2-Nitro-4,5-dimethoxyphenyl Ketone and Nitromethane	NaOC_2H_5	4-Nitro-1-(2'-nitro-4',5'-dimethoxyphenyl)-3-phenylbutan-1-one	710

Substituent R in	Addend	Catalyst	Product (Yield, %)	References
				
C_2H_5S	Diethyl malonate	KOH	 (68)	155
	Diethyl acetamidomalonate	KOH	 (8) and  (42)	155

Note: References 491–1045 are on pp. 545–555.

TABLE VIII—Continued

ROBINSON'S MODIFICATION OF THE MICHAEL CONDENSATION OF α,β -ETHYLENIC KETONES			
Substituent R in	Addend	Catalyst	Product (Yield, %)
CH_2R 			
	Dibenzoylmethane	HCl, C ₂ H ₅ OH	 (53)
			736, cf. 737, 738
C ₄ H ₉ S	2-Nitropropane	NaOH	 (56)
			155
Indole		KOH	 (52)
			155
Substituent R in			
$\text{RC}_6\text{H}_4\text{CH}(\text{NO}_2)\text{CH}_3$			
$(\text{C}_6\text{H}_5)_2\text{N}$	Diethyl malonate	NaOC_4H_9 NaOC_2H_5 $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{A} = \text{CH}_3\text{CH}(\text{NO}_2)\text{CH}_2-$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (37) $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (25) $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (47)
			251 251 251






	Diethyl malonate	NaOC_4H_9	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (13)	251
	Ethyl acetoacetate	NaOC_2H_5 ; NaOC_4H_9	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (46)	251
	Ethyl acetoacetate	NaOC_4H_9	$(\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5)$ (17)	251
	Ethyl x-acetylsuccinate	NaOC_4H_9	$\text{C}_2\text{H}_5\text{O}_2\text{CC}(\text{A})(\text{COCH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (72)	251
	Ethyl x-acetylsuccinate	NaOC_4H_9	$\text{C}_2\text{H}_5\text{O}_2\text{CC}(\text{A})(\text{COCH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (8)	251
	1-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ NaOH	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (33)	251
	2-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ NaOH	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (50)	251
			$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (52)	251
			$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (43)	251
Substituent R in $\text{RCH}_2\text{CH}_2\text{CH}_2\text{NO}_2$, $\text{CH}_3\text{CH}_2\text{CH}_3$				
	1-Nitropropane	NaOH	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (34)	251, 739
	1-Nitropropane	NaOH	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (18)	251, 739
	1-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{C}_2\text{H}_5)_3]\text{OH}$ NaOH	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (15)	251
	2-Nitropropane	NaOH	$\text{CH}_3\text{CH}_2\text{CH}(\text{A})\text{NO}_2$ (18)	251, 739
	2-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{C}_2\text{H}_5)_3]\text{OH}$ NaOH	$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (55)	251
	2-Nitropropane		$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (50)	251
			$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$ (44)	251

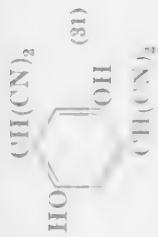

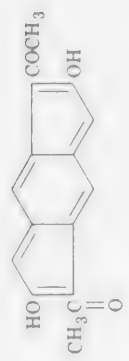
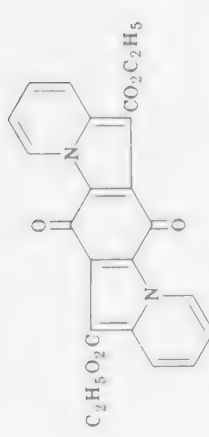
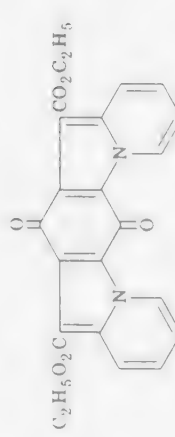
$$\text{A} = \text{CH}_3\text{CH}_2\text{CH}(\text{NO}_2)\text{CH}_2-$$

Note: References 491-1045 are on pp. 545-555.

TABLE IX

MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>p</i> -Benzoquinone and Ethyl acetoacetate	ZnCl_2 (1)		256
$\text{CH}_3\text{C}(=\text{O})\text{NHCH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$	None		377
$\text{CH}_3\text{C}(=\text{O})\text{NHCH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$	None		377
Ethyl cyanoacetate	NH_3 , ethanol		252
Cyanoacetamide	NH_3 , ethanol		252

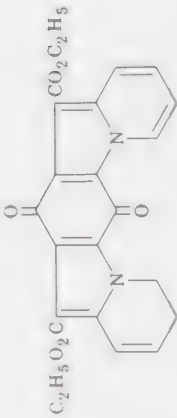
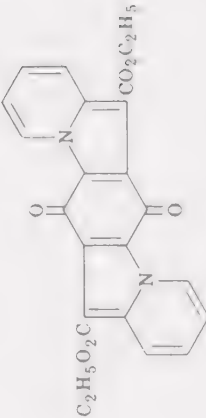
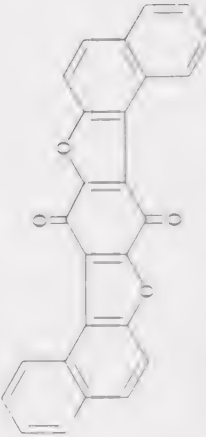
Malononitrile	NH ₃ , ethanol		252
Acetylacetone	Pyridine		740
			741
			272
			

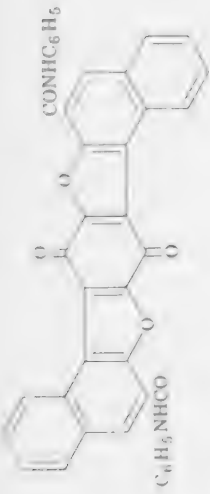

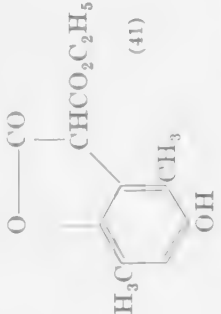
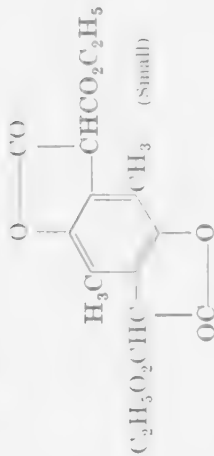
2,6-Dichlorobenzoquinone and

Note: References 491-1045 are on pp. 545-555.

* This is the formula assumed by the author.

TABLE IX—Continued

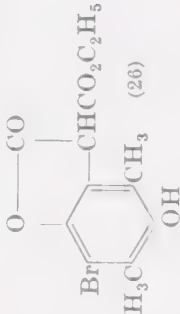
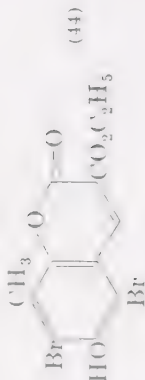


MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES	Reactants	Catalyst	Product (Yield, %)	References
<i>Chloroquinol and</i>	Reactants	Catalyst		References
Ethyl acetoacetate		Pyridine		272
β -Naphthol		Pyridine		272

2-Hydroxy-3-naphthamide	Pyridine		272
Methoxybenzoquinone and $\text{CH}_3\text{C}(\text{O})\text{—NHCH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$	None	 (72) $\text{C}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)\text{C}(=\text{NH})\text{CH}_3$	377
$\text{C}_2\text{H}_5\text{OC}(\text{O})\text{—NHCH}_2\text{CO}_2\text{C}_2\text{H}_5$ <i>p</i> -Xyloquinone and	None	Ethyl 2-ethoxy-5-hydroxy-6-methoxyindole-3-carboxylate† (46)	377
Diethyl malonate	NaOC_2H_5	 (41)	742
			

Note: References 491–1045 are on pp. 545–555.

† The position of the methoxyl group has not been determined.

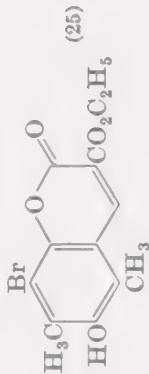
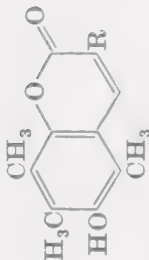
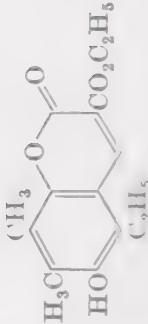
TABLE IX *Continued*
MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES

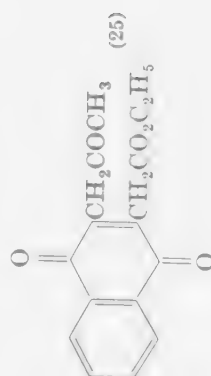
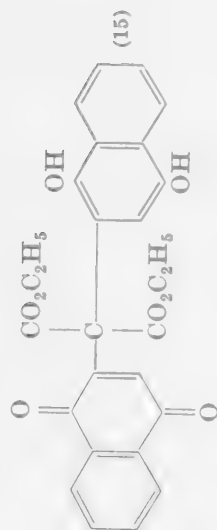
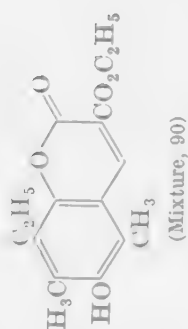
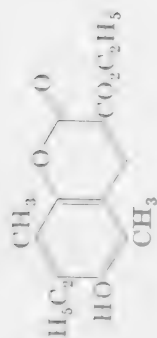
Reactants	Catalyst	Product (Yield, %)	References
2-Bromo-3,5-dimethylbenzoquinone and Diethyl malonate	NaOOC_2H_5	 (26)	743
3,5-Dibromo-2,6-dimethylbenzoquinone and Diethyl malonate	Na	 (44)	744
Trimethylbenzoquinone and Diethyl malonate	NaOOC_2H_5	 (27)	253, 745
Ethyl acetoacetate	$\text{NaOOC}_2\text{H}_5; \text{Na}$	 (20)	745
Ethyl palmitoylacetate and Ethyl stearoylacetate	$\text{NaOOC}_2\text{H}_5; \text{Na}$	$A, R = \text{COCH}_3$ (55) $A, R = \text{COC}_{16}\text{H}_{31}$ (27) $A, R = \text{COC}_{17}\text{H}_{35}$ (27)	745 746 746

Diethyl isobutyrylmalonate	NaOC_2H_5 ; $\text{Mg}(\text{OC}_2\text{H}_5)_2$	$A, R = \text{CO}_2\text{C}_2\text{H}_5$ (56)	253
Ethyl cyanoacetate	Na	Ethyl trimethylhydroquinonecyanoacetate (32)	388
Trimethylbenzoquinone and		$A = \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C} \text{---} \text{C}_6\text{H}_2 \text{---} \text{O} \text{---} \text{C}(=\text{O}) \\ \quad \quad \\ \text{HO} \quad \text{HO} \quad \text{R} \\ \\ \text{CH}_3 \end{array}$ $B = \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C} \text{---} \text{C}_6\text{H}_2 \text{---} \text{OH} \\ \quad \quad \\ \text{HO} \quad \text{HO} \quad \text{R}' \\ \\ \text{CH}_3 \end{array}$	
Cyanoacetamide	NaOCH_3	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C} \text{---} \text{C}_6\text{H}_2 \text{---} \text{O} \text{---} \text{NH}_2 \\ \quad \quad \\ \text{HO} \quad \text{HO} \quad \text{CN} \\ \\ \text{CH}_3 \end{array} \text{ or } \begin{array}{c} \text{H} \\ \\ \text{CH}_3 \text{---} \text{N} \text{---} \text{C}(=\text{O}) \\ \quad \quad \\ \text{H}_3\text{C} \text{---} \text{C}_6\text{H}_2 \text{---} \text{OH} \\ \quad \quad \\ \text{HO} \quad \text{HO} \quad \text{CN} \\ \\ \text{CH}_3 \end{array}$ (74-83)	388
Benzyl cyanide	NaOCH_3	$A, R = \text{C}_6\text{H}_5$ (32)	388
Acetylacetone	NaOC_2H_5	$B, R' = \text{CH}_3\text{COCHCOCH}_3$ (72)	259
Isobutyrylacetone	NaOC_2H_5	$B, R' = \text{CH}_3\text{COCHCOCH}(\text{CH}_3)_2$ (81)	259
2,6-Dimethylheptane-3,5-dione	NaOC_2H_5	$B, R' = (\text{CH}_3)_2\text{CHCOCHCOCH}(\text{CH}_3)_2$ (76)	260
Heptadecane-2,4-dione	NaOC_2H_5	$B, R' = \text{CH}_3\text{COCHCOCHC}_{13}\text{H}_{27-n}$ (14)	254
5,9,13,17-Tetramethyloctadecane-2,4-dione	NaOC_2H_5	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C} \text{---} \text{C}_6\text{H}_2 \text{---} \text{O} \text{---} \text{CH}(\text{CH}_3)(\text{CH}_2)_3\text{CH}(\text{CH}_3)(\text{CH}_2)_3\text{---} \\ \quad \quad \quad \quad \\ \text{HO} \quad \text{HO} \quad \text{CH}(\text{CH}_3)(\text{CH}_2)_3\text{CH}(\text{CH}_3)(\text{CH}_2)_3 \\ \\ \text{CH}_3 \end{array}$ (21)	254
Acetomesitylene	Bromomagnesium enolate	$B, R' = \text{CH}_2\text{COC}_6\text{H}_2(\text{CH}_3)_3$ (90)	253

Note: References 491-1045 are on pp. 545-555.

TABLE IX—Continued
MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Bromotrimethylbenzoquinone and</i>			
Diethyl malonate	NaOC_2H_5	 (25)	747
<i>Duroquinone and</i>			
Diethyl malonate	Na	 R = $\text{CO}_2\text{C}_2\text{H}_5$	201, cf. 747a, 747b
Ethyl acetoacetate	Na	R = COCH_3 (25)	263
Methyl cyanoacetate	Ni	R = CN (26)	262
<i>Trimethylethylbenzoquinone and</i>			
Diethyl malonate	Na		748



1,4-Naphthoquinone and

Diethyl malonate

Pyridine

267

Ethyl acetate

NaOH, ethanol

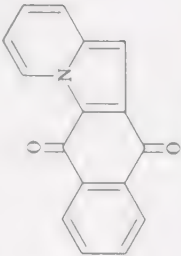
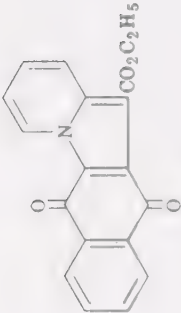
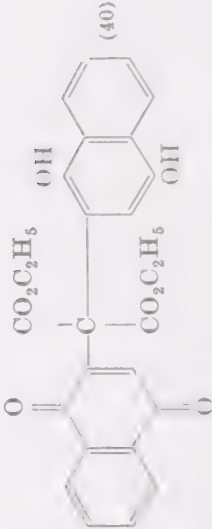
268

Note: References 491-1045 are on pp. 545-555.

TABLE IX—Continued
MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES

References

1,4-Naphthoquinone (Cont.) and

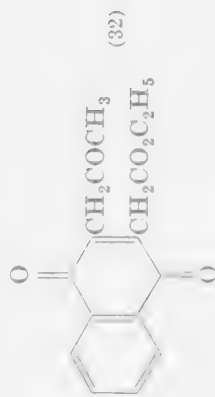
Reactants	Catalyst	Product (Yield, %)	References
Ethyl acetoacetate (Cont.)	Pyridine, pyridine hydrochloride	 (14)	266
Ethyl benzoylacetate	Pyridine, pyridine hydrochloride	 (16)	269
Potassium 1,4-naphthoquinone-2-sulfonate and			
Diethyl malonate	Pyridine	 (40)	267



266

(CH₃)₄NOH

Ethyl acetate

2-Bromo-1,4-naphthoquinone and

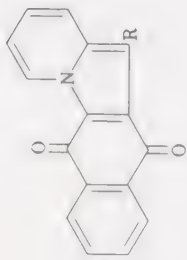
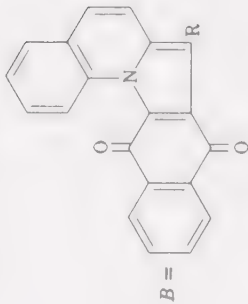
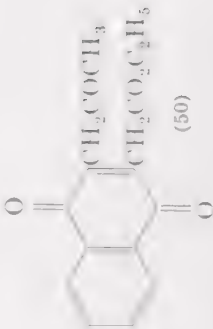
266

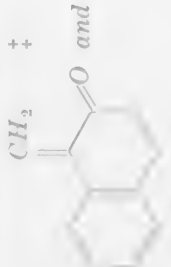
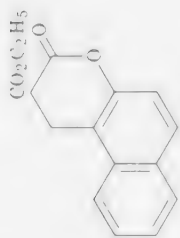
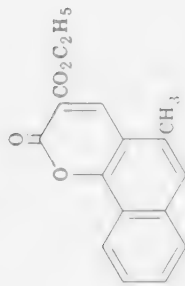
KOH, aq. ethanol

Ethyl acetate

TABLE IX—Continued

MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES




Reactants	Catalyst	Product (Yield, %)	References
2,3-Dichloro-1,4-naphthoquinone and		 A =	
		 B =	
Dimethyl malonate	Quinoline, quinoline hydrochloride	B, R = CO ₂ CH ₃ (20)	266
Diethyl malonate	Pyridine	A, R = CO ₂ C ₂ H ₅ (6)	269
	Quinoline, quinoline hydrochloride	B, R = CO ₂ C ₂ H ₅ (11)	266
Methyl acetoacetate	Pyridine, pyridine hydrochloride	A, R = CO ₂ CH ₃ (51)	266
	Quinoline, quinoline hydrochloride	B, R = CO ₂ CH ₃ (39)	266
Ethyl acetoacetate	Pyridine, pyridine hydrochloride	A, R = CO ₂ C ₂ H ₅ (49, 62)	266, 269
	or		
		 (50)	266

Acetoacetanilide	Quinoline, quinoline hydrochloride	$B, R = CO_2C_2H_5$ (45)	266
Acetoacet-o-chloroanilide	Pyridine	$A, R = COCH_3$ (31) and $A, R = CONHC_6H_5$ (8)	271, 272
Acetoacet-o-toluide	Pyridine	$A, R = COCH_3$	271, 272
2-(Acetoacetamido)-6-ethoxy- 4-methylquinoline	Pyridine	$A, R = COCH_3$	271, 272
Acetylacetate	Pyridine	$A, R = COCH_3$ (36)	269
Acetophenone	Pyridine	$A, R = COC_6H_5$ (13)	273
Diethyl malonate	Pyridine	$A, R = COC_6H_5$ (3)	273
			
Diethyl malonate	Na	 (small)	265
2,3-Dimethyl-1,4-naphthoquinone and			
Diethyl malonate	Na	 (45)	749

Note: References 491-1045 are on pp. 545-555.

+ This quinone was introduced as its dimer.

TABLE IX—Continued
MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
$\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{OC}_6\text{H}_5$ <i>and</i> $\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{OC}_6\text{H}_5$	NaOCH_3 NaOCH_3	NHCOC_6H_5  $A =$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (76) $\text{CH}_3\text{COCH}(A)\text{COCH}_3$ (75)	749a 749a
$\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{OC}_6\text{H}_5$ <i>and</i> $\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{SO}_2\text{C}_6\text{H}_5$	NaOCH_3 NaOCH_3	 $A =$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (57) $\text{CH}_3\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (90 crude)	750 750
$\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{OC}_6\text{H}_5$ <i>and</i> $\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{SO}_2\text{C}_6\text{H}_5$	NaOCH_3 NaOCH_3	 $A =$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (97 crude)	750
$\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{OC}_6\text{H}_5$ <i>and</i> $\text{N} \begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array} \text{SO}_2\text{C}_6\text{H}_5$	NaOCH_3 NaOCH_3	$\text{C}_6\text{H}_5\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (94 crude) $\text{CH}_3\text{COCH}(A)\text{COCH}_3$ (25 crude)	750 750

Cyclohexene-1,3-dione

NaOCH₃

750



and



Diethyl malonate
Ethyl acetoacetate
Acetylacetone

NaOCH₃
NaOCH₃
NaOCH₃

ACH(CO₂C₂H₅)₂ (62)
CH₃COCH(A)CO₂C₂H₅ (97 crude)
CH₃COCH(A)COCH₃ (94 crude)



and



Diethyl malonate
Ethyl acetoacetate
Acetylacetone





NaOCH₃
NaOCH₃
NaOCH₃

ACH(CO₂C₂H₅)₂ (82)
CH₃COCH(A)CO₂C₂H₅ (95 crude)
CH₃COCH(A)COCH₃ (79)

Note: References 491-1045 are on pp. 545-555.

At 66.665 compound, ethyl cyanoacetate, malononitrile, nitromethane, nitroethane and 2-nitropropane gave only tarry products.

TABLE IX—Continued


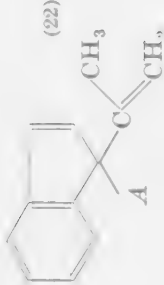
MICHAEL CONDENSATIONS WITH QUINONES AND THEIR DERIVATIVES		References	
Reactants	Catalyst	Product (Yield, %)	References
$\text{NHSO}_2\text{C}_6\text{H}_5$  <i>and</i> $\text{NHSO}_2\text{C}_6\text{H}_5$		 $\text{A} =$	
Diethyl malonate	$(\text{C}_2\text{H}_5)_3\text{N}$	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (83)	751
Ethyl benzoylacetate	$(\text{C}_2\text{H}_5)_3\text{N}$	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (90)	751
Aceylacetone	$(\text{C}_2\text{H}_5)_3\text{N}$	$\text{CH}_3\text{COCH}(\text{A})\text{COCH}_3$ (84)	751
Nitromethane	$(\text{C}_2\text{H}_5)_3\text{N}$	$(\text{A})_2\text{CHNO}_2$ (84)	751
Nitroethane	$(\text{C}_2\text{H}_5)_3\text{N}$	$\text{ACH}(\text{CH}_3)\text{NO}_2$ (64)	751
NCOC_6H_5 <i>and</i> $=\text{NCOC}_6\text{H}_5$		$\text{A} =$ 	
Diethyl malonate	NaOCH_3	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (96)	752
Aceylacetone	NaOCH_3	$\text{CH}_3\text{COCH}(\text{A})\text{COCH}_3$ (99)	752
NCOC_6H_5 <i>and</i> $=\text{NCOC}_6\text{H}_5$			
Aceylacetone	NaOCH_3	(97)	752

Note: References 491–1045 are on pp. 545–555.

The position in which the substitution has taken place has not been determined.

¶ With diethyl malonate, this compound gave only an oily product.

TABLE X
MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>A. Hydrocarbons</i>			
Cyclopentadiene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	Hexa-(β -cyanoethyl)cyclopentadiene (9)	288
Indene	$(C_6H_5CH_2)_2N(CH_3)_3[OH]$	<i>x,x</i> -Bis-(β -cyanoethyl)indene (14)	288
		1,1,3-Tris-(β -cyanoethyl)indene (35)	
1-Isopropylideneindene	$(C_6H_5CH_2)_2N(CH_3)_3[OH]$	<div style="display: flex; align-items: center; justify-content: center;">  or  </div>	288
Fluorene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	9,9-Di-(β -cyanoethyl)fluorene (74)	288, 753
1-Methylfluorene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	9,9-Di-(β -cyanoethyl)-1-methylfluorene (70)	482
2-Nitrofluorene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	9,9-Di-(β -cyanoethyl)-2-nitrofluorene (70)	288
2,7-Dibromofluorene	Not indicated	2,7-Dibromo-9,9-di-(β -cyanoethyl)fluorene	754
4,5-Methylenephenanthrene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	4,5-Di-(β -cyanoethyl)methylenephenanthrene	754, 755
9-Phenylfluorene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	9-(β -Cyanoethyl)-9-phenylfluorene (73)	289
9-Fluorenyl	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	9-(β -Cyanoethyl)-9-fluorenyl	289
1,2,3,4-Tetrahydrofluoranthene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	1-(β -Cyanoethyl)-1,2,3,4-tetrahydrofluoranthene	754, 755
2,2,4-Trimethyl-1,2-dihydrofluoranthene	$(C_6H_5CH_2)_3N(CH_3)_3[OH]$	1-(β -Cyanoethyl)-2,2,4-trimethyl-1,2-dihydrofluoranthene	754, 755
<i>B. Aldehydes</i>			
Acetaldehyde	—	$A = -CH_2CH_2CN$	756
Propionaldehyde	—	$(A)_2CHCHO, (A)_3CCHO$ $CH_3CH(A)CHO, CH_3C(A)_2CHO$	756

Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*			
Reactants	Catalyst	Product (Yield, %)	References
<i>B. Aldehydes (Contd.)</i>			
Isobutyraldehyde	Quaternized polyvinylpyridine resin; aq. KCN	$(\text{CH}_3)_2\text{C}(\text{A})\text{CHO}$ (40, 79) $\text{A} = -\text{CH}_2\text{CH}_2\text{CN}$	478, 756, 757
Dihydroacetaldehyde	KOH, CH_3OH	$(\text{C}_2\text{H}_5)_2(\text{A})\text{CHO}$ (75–80)	278, 284
2-Ethyl 2-hexenal	KOH	$\text{CH}_3\text{CH}_2\text{CH}=\text{CHC}(\text{A})(\text{C}_2\text{H}_5)\text{CHO}$ (50)	284
2-Ethylhexenal	KOH, CH_3OH	$\text{C}_4\text{H}_9\text{C}(\text{A})(\text{C}_2\text{H}_5)\text{CHO}$ (75, 80)	278, 284
<i>n</i> -Phenylpropionaldehyde	KOH	$(\text{C}_6\text{H}_5)(\text{CH}_3)(\text{A})\text{CHO}$ (74)	758
<i>C. Ketones</i>			
Acetone	Quaternized polyvinylpyridine resin NaOH	$\text{A} = -\text{CH}_2\text{CH}_2\text{CN}$ $\text{CH}_3\text{COCH}_2\text{A}$ (19) and $\text{CH}_3\text{COC}(\text{A})_3$ (32)	478
		$\text{CH}_3\text{COCH}_2\text{A}$ (8), $\text{CH}_3\text{COCH}(\text{A})_2$ (14), $\text{CH}_3\text{COC}(\text{A})_3$ (24)	759
	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{COC}(\text{A})_3$ (75–80) and $(\text{A})_2\text{CHCOC}(\text{A})_3$	760, 761
	$(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}$ Na;	$\text{CH}_3\text{COCH}_2\text{A}$ (18)†	762
	$(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}$ KOH, $\text{C}_2\text{H}_5\text{OH}$;	$\text{CH}_3\text{COC}(\text{A})\text{CH}_3$ (51, 90) and $(\text{A})_2\text{CHCOC}(\text{A})_2\text{CH}_3$	763, 761
Methyl ethyl ketone	$(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}$ KOH, $\text{C}_2\text{H}_5\text{OH}$;	$\text{CH}_3\text{COCH}(\text{A})\text{CH}_3$ (6, 20) and $\text{CH}_3\text{COC}(\text{A})_2\text{CH}_3$ (47)†	275, 278
	$(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}$	$\text{CH}_3\text{COCH}(\text{A})\text{CH}_3$ and $\text{CH}_3\text{COC}(\text{A})_2\text{CH}_3$ (24–30)†	762
	Polyvinylpyridine resin Aq. KCN	$\text{CH}_3\text{COCH}(\text{A})\text{CH}_3$ and $\text{CH}_3\text{COC}(\text{A})_2\text{CH}_3$ (total, 47)	178
Methyl isobutyryl ketone	KOH, $\text{C}_2\text{H}_5\text{OH}$;	$\text{CH}_3\text{COC}(\text{A})_2\text{CH}_2\text{CN}$ (82)	123
Methyl <i>n</i> -propyl ketone	$(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}$; quaternized polyvinylpyridine resin	$\text{CH}_3\text{COCH}(\text{A})\text{C}_2\text{H}_5$ (15, 20), $\text{CH}_3\text{COC}(\text{A})_2\text{C}_2\text{H}_5$ (14, 43), and $\text{A}\text{CH}_2\text{COC}(\text{A})_2\text{C}_2\text{H}_5$	275, 278, 478, 761

Methyl isopropyl ketone	KOH, C_2H_5OH ; [$C_6H_5CH_2N(CH_3)_3$]OH	$CH_3COC(A)CH(CH_3)_2$ (51)†	275
Diethyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH	$CH_3CH(A)COC(A)CH_3$ (31)	761
Methyl isobutyl ketone	KOH, C_2H_5OH ; [$C_6H_5CH_2N(CH_3)_3$]OH	$CH_3COC(A)CH(CH_3)_2$ (17) and $CH_3COC(A)_2CH(CH_3)_2$ (15)†	275, 761
Methyl isopentyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH	$CH_3COC(A)_2C(CH_3)=CH_2$ (35, 74) and $CH_3COC(A)_2C(CH_3)_2$ (10-13)	764, 283
Methyl <i>n</i> -amyl ketone	KOH, C_2H_5OH ; [$C_6H_5CH_2N(CH_3)_3$]OH	$CH_3COC(A)C_4H_9-n$ (19) and $CH_3COC(A)_2C_4H_9-n$ (40)†	275, 761
Diisopropyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH	$(CH_3)_2C(A)COCH(CH_3)_2$ (40, 10) and $(CH_3)_2C(A)COC(A)(CH_3)_2$ (1)†	274, 275, 765
	Aq. NaOH	$(CH_3)_2C(A)COCH(CH_3)_2$ (28) and $(CH_3)_2C(A)COC(A)(CH_3)_2$ (small)	766
Methyl hexyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH; KOH, C_2H_5OH	$CH_3COC(A)C_5H_{11-n}$ (19) and $CH_3COC(A)_2C_5H_{11-n}$ (31)†	275, 761
Isobutyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH; KOH, C_2H_5OH	$(CH_3)_2CHCH(A)COCH_2CH(CH_3)_2$ (35) and $(CH_3)_2CHCH(A)COC(A)CH(CH_3)_2$ (19)†	275
Isopropyl <i>n</i> -amyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH; KOH, CH_3OH	$n-C_5H_{11}COC(A)CH(CH_3)_2$	276
Isopropyl <i>n</i> -nonyl ketone	[$C_6H_5CH_2N(CH_3)_3$]OH; KOH, CH_3OH	$n-C_9H_{19}COC(A)CH(CH_3)_2$	276
Acetylacetone	[$C_6H_5CH_2N(CH_3)_3$]OH or OC_4H_9-n	$CH_3COC(A)_2COCH_3$ (49-55)	277
Acetylacetone	[$C_6H_5CH_2N(CH_3)_3$]OH or OC_4H_9-n	$CH_3COC(A)_2CH_2COC(A)_2CH_3$ (46-50)	277
Cyclopentanone	[$C_6H_5CH_2N(CH_3)_3$]OH; KOH	2,2,5,5-Tetra-(β -cyanoethyl)cyclopentanone (97)	761
	[$C_6H_5CH_2N(CH_3)_3$]OH; [$C_6H_5N(CH_3)_3$]OC $_2$ H $_5$	2,2,5,5-Tetra-(β -cyanoethyl)cyclopentanone (95-97)	767

Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴

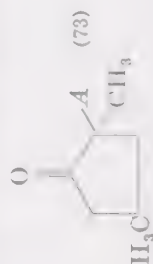
† A large excess of the ketone was used in this experiment.

‡ The acrylonitrile was formed *in situ* from β -chloropropionitrile in the experiments described in ref. 275.

TABLE X—*Continued*

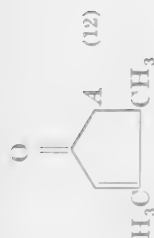
MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>C. Ketones (Cont.)</i>		$A = -CH_2CH_2CN$	
Cyclohexanone	KOH, C_6H_5OH ; $[C_6H_5CH_2N(CH_3)_3]OH$ $[C_6H_5CH_2N(CH_3)_3]OH$	2-(β -Cyanoethyl)cyclohexanone (16-19) and 2,2-di-(β -cyanoethyl)cyclohexanone (44)† 2-(β -Cyanoethyl)cyclohexanone (47) or 2,2-di-(β -cyanoethyl)cyclohexanone (18-20)	114, 234, 275 762, 168
	$NaNH_2$	2,2,6,6-Tetra-(β -cyanoethyl)cyclohexanone (12)§	275, 284
	Na; $[C_6H_5CH_2N(CH_3)_3]OH$; KOH	2,2,6,6-Tetra-(β -cyanoethyl)cyclohexanone (81, 80-95)	761, 763
	NaOH	2-(β -Cyanoethyl)cyclohexanone (20) and 2,2-Di-(β -cyanoethyl)cyclohexanone (40)	768
	Enamine of the ketone with pyrrolidine	2-(β -Cyanoethyl)cyclohexanone (80)	535
	$NaOC_2H_5$	2-(β -Cyanoethyl)cyclohexanone (5), 2,2-di-(β -cyano-ethyl)cyclohexanone (5), and 2,2,6,6-tetra-(β -cyano-ethyl)cyclohexanone	766
	KOH	2-(β -Cyanoethyl)cyclohexanone (29) and 2,2-di-(β -cyanoethyl)cyclohexanone (26)	769
Cyclohexane-1,3-dione	$NaOCH_3$	2-(β -Cyanoethyl)cyclohexane-1,3-dione (23)	770



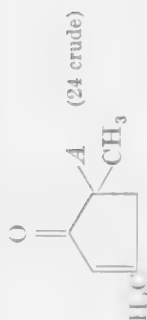
2,4-Dimethylcyclopentanone KOH 769

769



2,4-Dimethyl-2-cyclopentanone Not indicated

769



2-Methyl-2-cyclohexanone Not indicated

114

2-Methyl-2-(β -cyanoethyl)cyclohexanone (80)

761

2-Methyl-2,6,6-tri-(β -cyanoethyl)cyclohexanone (38)

114

2-(β -Cyanoethyl)-4-methylcyclohexanone (21)

769

2-(β -Cyanoethyl)-2-methylcyclohexane-1,3-dione (82) ||

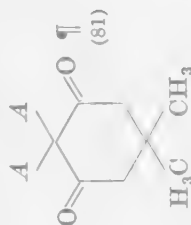
771

1-Carbethoxy-7-cyano-5-methylheptan-4-one (63)

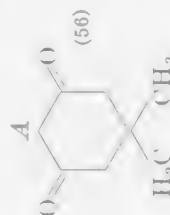
535

2-(β -Cyanoethyl)cycloheptan-1-one

772

2-(β -Cyanoethyl)-2-cyanocycloheptan-1-one (65)

or

NaOCH₃

5,5-Dimethylcyclohexane-1,3-dione

769

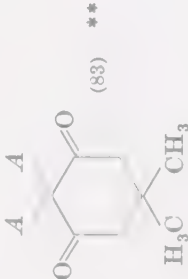
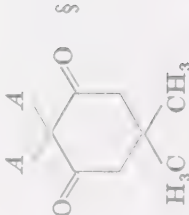
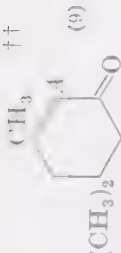
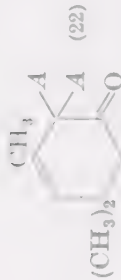
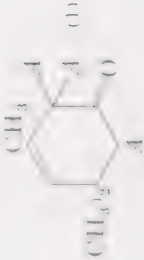
Note: References 491-1045 are on pp. 545-555.* Compare the review by Bruson.²⁷⁴1. The acrylonitrile was formed from β -chloropropionitrile in the experiments described in reference 275.2. The acrylonitrile was formed *in situ* from the methiodide of 2-diethylaminoethyl cyanide.

3. The acrylonitrile was formed under more drastic conditions, this product is hydrolyzed to 7-cyano-5-methyl-4-oxoheptano-1-carboxylic acid (74).

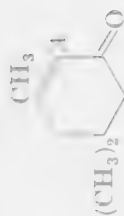
4. Under more drastic conditions, part of the product was hydrolyzed to 5-(β -cyanoethyl)-7-cyano-2,2-dimethyl-4-oxoheptano-1-carboxylic acid.

TABLE X—*Continued*

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>C. Ketones (Cont.)</i>		$A = -CH_2CH_2CN$	
5,5-Dimethylcyclohexane-1,3-dione (Cont.)	$NaOC_2H_5$	 (83) **	234
	$NaNH_2$	 §	234
Isophorone	$[C_8H_5CH_2N(CH_3)_3]OH$	 †† (9)	285
		 (22)	
		 (11)	

286

 $\text{N}(\text{C}_2\text{H}_5)_2$

761

2,2,6,6-Tetra-(β -cyanomethyl)-4-*tert*-butylcyclohexanone (80-95) $\text{C}_{20}\text{H}_{34}\text{N}_4\text{O}(\text{CH}_3)_3\text{OH}$
KOH

279

2-Cyclohex-1-enyl-2-(β -cyanomethyl)cyclohexanone (50) and 2-cyclohex-1-enyl-2,6,6-tri-(β -cyanomethyl)cyclohexanone (29) $\text{C}_{20}\text{H}_{34}\text{N}_4\text{O}(\text{CH}_3)_3\text{OH}$

761

2,2,6,6-Tetra-(β -cyanomethyl)-4-cyclohexylcyclohexanone (80-95) $\text{C}_{24}\text{H}_{40}\text{N}_4\text{O}(\text{CH}_3)_3\text{OH}$
KOH

(16)

 $\text{C}_{24}\text{H}_{40}\text{N}_4\text{O}(\text{CH}_3)_3\text{OH}$

108

Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁸¹

† The acrylonitrile was formed *in situ* from the methide of 2-diethylaminoethyl cyanide.

** The diketone was recovered to an extent of 34%. When β -chloropropionitrile was employed instead of acrylonitrile, the yield was 21%, and 52% of the diketone was recovered.

†† This structure has been proven (ref. 286) by isomerization to 3,3-dimethyl-5-oxohexane-1-carboxylic acid. In ref. 285, the isomeric form was incorrectly assigned to the monosubstitution product.

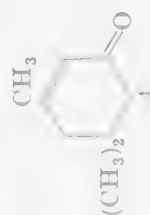
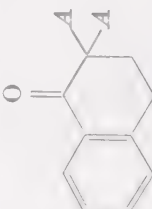
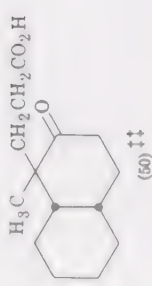
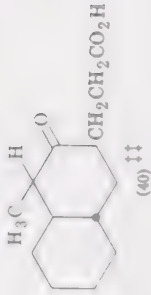
 $(\text{CH}_3)_2$

TABLE X—Continued

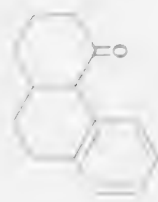
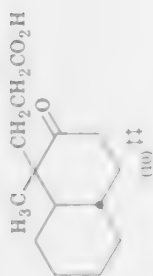
MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>C. Ketones (Cont.)</i>		$A = -CH_2CH_2CN$	
2-Phenylcyclohexanone	$NaNH_2$ $[C_6H_5CH_2N(CH_3)_3]OH$ Na	2-(β -Cyanoethyl)-2-phenylcyclohexanone (63-70)	112
4-($\alpha,\alpha,\gamma,\gamma$ -Tetramethylbutyl)-cyclohexanone	$[C_6H_5CH_2N(CH_3)_3]OH$	2-(β -Cyanoethyl)-2-phenylcyclohexanone (60)	113
2-Benzylidene-6-phenylcyclohexanone	$[C_6H_5CH_2N(CH_3)_3]OH$	2,2,6,6-Tetra-(β -cyanoethyl)-4-($\alpha,\alpha,\gamma,\gamma$ -tetramethylbutyl)cyclohexanone (80-95)	773
		2-Benzylidene-6-(β -cyanoethyl)-6-phenylcyclohexanone (83)	761
α -Tetralone	$[C_6H_5CH_2N(CH_3)_3]OH$; KOH		112
			761
1-Methyl- <i>cis</i> -2-decalone	$[C_6H_5CH_2N(CH_3)_3]OH$	 (50) ††	368
1-Methyl- <i>trans</i> -2-decalone	$[C_6H_5CH_2N(CH_3)_3]OH$	 (40) ††	368

3-(Methylanilino)methylene)-1-methyl-*trans*-2-decalone

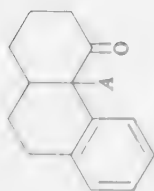
$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$

308



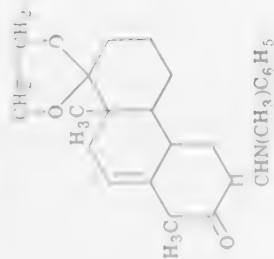
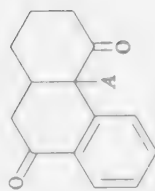
$[\text{C}_8\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$

108



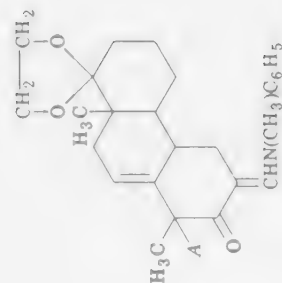
$[\text{C}_8\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$

108



$[\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_3]\text{OH}$

542



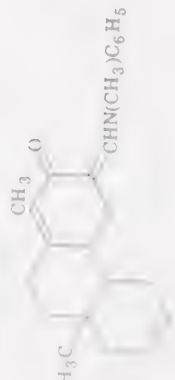
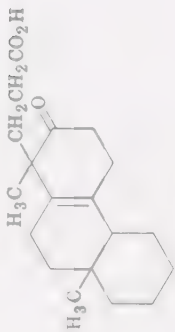
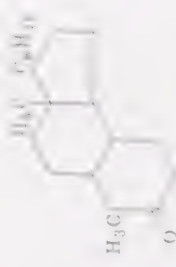
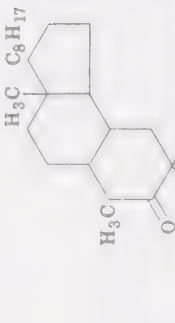
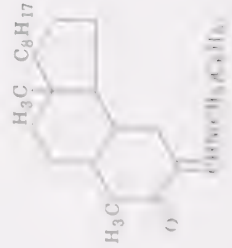
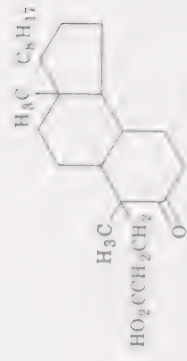
Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴

++ This product was isolated after saponification of the adduct.

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>C. Ketones (Cont.)</i>		<i>A</i> = —CH ₂ CH ₂ CN	
 <chem>CC1=C(C(=O)C(=CC=C1)C(=O)C2=CC=CC=C2)C3=CC=CC=C3</chem>	(C ₆ H ₅) ₃ N(C(CH ₃) ₃)OH	 <chem>CC1=C(C(=O)C(=CC=C1)C(=O)C2=CC=CC=C2)C3=CC=CC=C3C(=O)CC(=O)C4=CC=CC=C4</chem>	774
 <chem>CC1=C(C(=O)C(=CC=C1)C(=O)C2=CC=CC=C2)C3=CC=CC=C3C(=O)CC(=O)C4=CC=CC=C4</chem> (Inhoffen ketone)	(C ₆ H ₅) ₃ N(C(CH ₃) ₃)OH	 <chem>CC1=C(C(=O)C(=CC=C1)C(=O)C2=CC=CC=C2)C3=CC=CC=C3C(=O)CC(=O)C4=CC(=O)C(=O)C5=CC=CC=C5C(=O)CC(=O)C6=CC=CC=C6</chem>	368
 <chem>CC1=C(C(=O)C(=CC=C1)C(=O)C2=CC=CC=C2)C3=CC=CC=C3C(=O)CC(=O)C4=CC(=O)C(=O)C5=CC=CC=C5C(=O)CC(=O)C6=CC=CC=C6</chem>	[C ₆ H ₅) ₃ N(C(CH ₃) ₃)OH	 <chem>CC1=C(C(=O)C(=CC=C1)C(=O)C2=CC=CC=C2)C3=CC=CC=C3C(=O)CC(=O)C4=CC(=O)C(=O)C5=CC(=O)C(=O)C6=CC=CC=C6C(=O)CC(=O)C7=CC=CC=C7</chem> (Wittmann acid)	368, 775


 $(C_6H_5N(CH_2)_3)_3OH$

551

Acetophenone

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
or OC_4H_9-n

277, 279,

Aq. KCN

761

 $[C_6H_5N(CH_2)_3)_3]OC_2H_5$
 $C_6H_5COCH(A)_2$ (30) and $C_6H_5COC(A)_3$ (small)

776

 $[C_6H_5CH_2N(CH_2)_3)]-$
 (OC_4H_9-n)
 $C_6H_5COC(A)_3$ (65)

767

 $[C_6H_5CH_2N(CH_2)_3)]-$
 (OC_4H_9-n)
 $C_6H_5COC(A)_3$ (64)

767

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $C_6H_5COC(A)_3$ (57)

767

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $p-ClC_6H_4COC(A)_3$

761

KOH

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $p-BrC_6H_4COC(A)_3$

761

KOH

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $p-CH_3C_6H_4COC(A)_3$

761

KOH

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $p-CH_3OC_6H_4COC(A)_3$

761

KOH

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $C_6H_5COC(A)_2CH_3$ (quant.)

761

KOH

 $[C_6H_5CH_2N(CH_2)_3)_3]OH$
 $C_6H_5C(A)_2COCH_3$ (86)

761

KOH

Na enolate

 $C_6H_5CH(A)COCH_3$ (80)

107

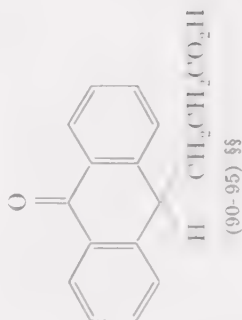
Note: References 491-1095 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴







TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>C. Ketones (Cont.)</i>			
Isobutyrophenone	KOH, CH ₃ OH	C ₆ H ₅ COC(A)(CH ₃) ₂	276
Isobutyrophenone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH or OC ₄ H ₉ - <i>n</i>	C ₆ H ₅ COC(A) ₂ (OC ₄ H ₉)	277
2,4,6-Trimethylacetophenone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH; KOH	2,4,6-(CH ₃) ₃ C ₆ H ₂ COC(A) ₃ (30)	761
Isopropyl benzyl ketone	KOH, CH ₃ OH	C ₆ H ₅ CH ₂ COC(A)(CH ₃) ₂	276
Methyl phenylthyl ketone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH	β -C ₁₀ H ₇ COC(A) ₃	761
α - <i>n</i> -Butylpropiphenone	KOH, CH ₃ OH	C ₆ H ₅ COC(A)(CH ₃)C ₄ H ₉ - <i>n</i>	276
<i>n</i> -Propylbutyropiphenone	KOH, CH ₃ OH	C ₆ H ₅ COC(A)(C ₂ H ₅)C ₃ H ₇ - <i>n</i>	276
Isobutyrophenone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH; KOH	C ₆ H ₅ C(A) ₂ COC ₆ H ₅ (80)	761
Anthrone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH	9,9-Di-(β -cyanoethyl)-10-anthrone (89)	288

KOC₄H₉-*t*

1-Phenylacetophenone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH; KOH	4-C ₆ H ₅ C ₆ H ₄ COC(A) ₃	761
Dibenzyl ketone	[C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH; KOH	C ₆ H ₅ C(A) ₂ COCCH ₂ CH ₂ C ₆ H ₅	761

2,4-Diethylpropionylfuran Methyl 2-phenylmethyl ketone	KOH, CH ₃ OH KOH, CH ₃ OH	$C_6H_5COC(A)(CH_3)C_8H_{17-n}$ $CH_3COC(A)CH(C_8H_{17-n})C_6H_5$	276 276
2-Acetylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$ or OC_4H_9-n	 $COC(A)_3$ (90-93)	277, 279
2-Acetyl-5-methylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$	 $COC(A)_3$ (71)	778
2-Ethylpropionylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$	 $COC(A)_2CH_3$ (Quant.)	279
1-Acetyl-2,5-dimethylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$	 $COC(A)_3$ (16)	778
2-Propionyl-5-methylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$	 $COC(A)_2CH_3$ (62)	778
2-2-Burylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$	 $COC(A)_2CH_2CH_3$ (70)	279
2,5-Dimethyl-3-propionylfuran	$[C_6H_5CH_2N(CH_3)_3]OH$	 $COC(A)CH_3$ (27)  $COC(A)_2CH_3$ (45)	778

Note: References 491-1045 are on pp. 545-555.






* Compare the review by Bruson.²⁷⁴

§§ Acrylonitrile was formed *in situ* from β -chloropropionitrile.

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

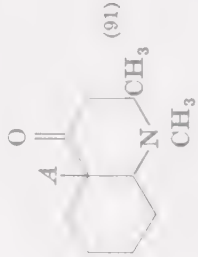
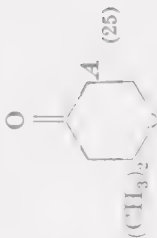


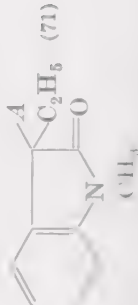
Reactants	Catalyst	Product (Yield, %)	References
<i>C. Ketones (Cont.)</i>			
<i>n</i> -Butyl 3-methylbutanoate	$(C_6H_5CH_2N(CH_2)_3)_3OH$	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COCH}(A) \text{C}_2\text{H}_5 \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COC}(A)_2\text{C}_2\text{H}_5 \\ \text{(23)} \end{array} $	778
<i>o</i> -Butyl 1,2,3-trimethylbutanoate	$(C_6H_5CH_2N(CH_2)_3)_3OH$	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COCH}(A)_2\text{C}_2\text{H}_5 \\ \text{(54)} \end{array} $	778
2-Acetylthiophene	$(C_6H_5CH_2N(CH_2)_3)_3OH$ or OC_4H_9-n	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COC}(A)_3 \\ \text{(87-89)} \end{array} $	277, 279
2-Acetyl 3-methylthiophene	$(C_6H_5CH_2N(CH_2)_3)_3OH$	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COC}(A)_3 \\ \text{(80)} \end{array} $	778
2-Propionylthiophene	$(C_6H_5CH_2N(CH_2)_3)_3OH$	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COC}(A)_2\text{CH}_3 \\ \text{(98)} \end{array} $	279
2-Methyl 3-propionylthiophene	$(C_6H_5CH_2N(CH_2)_3)_3OH$	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COC}(A)_2\text{CH}_3 \\ \text{(70)} \end{array} $	778
<i>n</i> -Butyl 3-bromo-2-methylbutanoate	$(C_6H_5CH_2N(CH_2)_3)_3OH$	$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COCH}(A) \text{C}_2\text{H}_5 \\ \text{(38)} \end{array} $	778
		$ \begin{array}{c} \text{H}_3\text{C} \diagup \text{O} \diagdown \text{COC}(A)_2\text{C}_2\text{H}_5 \\ \text{(48)} \end{array} $	

2-Acetyloxymethylpiperidine	$(C_6H_5CH_2N(C_2H_5)_2)OH$		(40)	277
5-Methyl-2-oxo-1,2,3,4-tetrahydropyridine	$(C_6H_5CH_2N(C_2H_5)_2)OH$		(43)	778
1,2,5-Trimethyl-4-piperidone	KOH		(90)	769
2,5-Dimethyl-1-ethyl-4-piperidone	KOH		(90)	769
1,2,3,6-Tetramethyl-4-piperidone	KOH		(70)	769

Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴

TABLE X—Continued

Reactants	Catalyst	Product (Yield, %)	References
<i>C. Adams (Cont.)</i>		$A = -CH_2CH_2CN$	
1,2-Dimethylacetaldehyde-1-(1H)-pyrrolidine	KOH	 (91)	769
2,2-Dimethyl-1-pyrone	KOH	 (25)	769
Kojic acid	$[C_6H_5CH_2N(CH_3)_3]OH$	 $\ddagger\ddagger$ (47)	170
3-Oxo-2,2,5,5-tetramethyltetrahydrofuran	$[C_6H_5CH_2N(CH_3)_3]OH$; KOH	 (63)	761
3-Ethyl-1-methylimidole	$[C_6H_5CH_2N(CH_3)_3]OH$	 (71)	779

17. Esters and Amides

Diethyl malonate	NaOC_2H_5 ; Na	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (57-63); $(\text{A})_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (12)	780, 781, 288, 781a
Malonamide	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $[\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_3]\text{OC}_2\text{H}_5$ $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ KOH, CH_3OH KOH, CH_3OH KOH, CH_3OH	$(\text{A})_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (82) $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (27); $(\text{A})_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (10) $(\text{A})_2\text{C}(\text{CONH}_2)_2$ (11) $\text{AC}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (93) α -Methylglutaric acid ^{††} α -Propylglutaric acid ^{††} α -n-Butylglutaric acid ^{††}	288 767 282 782 783 783 783
Diethyl n-propylmalonate	Na; NaOCH_3 ; NaOC_2H_5 ; $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	α -n-Butylglutaric acid ^{††}	282, 781, 784
Diethyl n-butylmalonate	NaOC_2H_5 ; NaOC_2H_5 NaOCH_3 ; NaOC_2H_5 NaOCH_3 ; NaOC_2H_5 NaOCH_3 ; NaOC_2H_5 NaOCH_3 ; NaOC_2H_5 NaOCH_3 ; NaOC_2H_5 $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	n -C ₄ H ₉ C(A)(CO ₂ C ₂ H ₅) ₂ (87-94) n -C ₆ H ₁₃ C(A)(CO ₂ C ₂ H ₅) ₂ (82) n -C ₈ H ₁₇ C(A)(CO ₂ C ₂ H ₅) ₂ (90) n -C ₁₀ H ₂₁ C(A)(CO ₂ C ₂ H ₅) ₂ (89) n -C ₁₂ H ₂₅ C(A)(CO ₂ C ₂ H ₅) ₂ (92) n -C ₁₄ H ₂₉ C(A)(CO ₂ C ₂ H ₅) ₂ (86) n -C ₁₆ H ₃₃ (A)(CO ₂ C ₂ H ₅) ₂ (89) $(\text{C}_6\text{H}_5\text{O}_2\text{C})_2\text{C}(\text{A})\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (77)	784 784 784 784 784 784 784 367
Diethyl n-hexylmalonate	KOH, CH_3OH NaOC_2H_5	α -Phenylglutaric acid ^{††} $\text{C}_6\text{H}_5\text{C}(\text{A})(\text{CO}_2\text{C}_2\text{H}_5)_2$ (72)	783 785
Diethyl n-octylmalonate	KOH, CH_3OH	α -Benzylglutaric acid ^{††}	783
Diethyl n-decylmalonate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_6\text{H}_5\text{CH}_2\text{C}(\text{A})(\text{CO}_2\text{C}_2\text{H}_5)_2$ (81)	283
Diethyl n-dodecylmalonate	KOH, CH_3OH	α -Phenethylglutaric acid ^{††}	783
Diethyl n-tetradecylmalonate	KOH, CH_3OH	α -(1-Naphthyl)glutaric acid ^{††}	783

Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴

†† This product was isolated after saponification of the adduct.

||| β -Ethoxypropionitrile was employed instead of acrylonitrile.

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*			References
Reactants	Catalyst	Product (Yield, %)	
<i>D. Esters and Amides (Cont.)</i>		$A = -CH_2CH_2CN$	
Diethyl 2-naphthylmalonate	KOH, CH ₃ OH	α -(2-Naphthyl)glutaric acid ††	783
Diethyl 1-naphthylmalonate	KOH, CH ₃ OH	α -(1-Naphthylmethyl)glutaric acid ††	783
Diethyl (2-naphthylmethyl)-malonate	KOH, CH ₃ OH	α -(2-Naphthylmethyl)glutaric acid ††	783
Diethyl (β -1-naphthylethyl)-malonate	KOH, CH ₃ OH	α -(β -1-Naphthylethyl)glutaric acid ††	783
Diethyl (β -2-naphthylethyl)-malonate	KOH, CH ₃ OH	α -(β -2-Naphthylethyl)glutaric acid ††	783
Vinylacetamide (or crotonamide)	$[C_6H_5CH_2N(C_2H_5)_3]OH$	$CH_2=CHC(A)_2CONH_2$ (18)	283
Diethyl β -4-methoxy-1-naphthylethylmalonate	KOH, CH ₃ OH, (CH ₃) ₃ COH	$ \begin{array}{c} CH_2CH_2CHCO_2H^{\dagger\dagger} \\ \\ \text{Naphthalene ring with } OCH_3 \text{ at } \beta \text{ position} \end{array} $ (40)	786
Diethyl β -5-methoxy-1-naphthylethylmalonate	KOH, CH ₃ OH, (CH ₃) ₃ COH	$ \begin{array}{c} CH_2CH_2CHCO_2H^{\dagger\dagger} \\ \\ \text{Naphthalene ring with } OCH_3 \text{ at } 5 \text{ position} \end{array} $ (32)	786

Diethyl β -oxo-methyl- γ -methyl- butyrylmalonate	KOH, CH ₃ OH, (CH ₃) ₂ COH		786
Diethyl β -oxo-methyl- γ -methyl- (3,5)-ethylmalonate	KOH, CH ₃ OH, (CH ₃) ₂ COH		786
Diethyl formamidomalonate	NaOC ₂ H ₅	(glutamic acid)++ (55)	459
Diethyl malonidomalonate	NaOC ₂ H ₅	CH ₃ CONHC(A)(CO ₂ C ₂ H ₅) ₂ (95)	458
Ethyl cyanoacetate	Aq. NaOH	NCCH(A)CO ₂ C ₂ H ₅ , NCC(A) ₂ CO ₂ C ₂ H ₅	469
Cyanoacetamide	[C ₆ H ₅ CH ₂ N(C ₂ H ₅) ₂]OH NaCN	NCC(A) ₂ CO ₂ C ₂ H ₅ (quant.)	367, 282
Ethyl α -isopropylcyanacetate	[C ₆ H ₅ CH ₂ N(C ₂ H ₅) ₂]OH KOH, CH ₃ OH	NCCH(A)CO ₂ C ₂ H ₅ and a little NCC(A) ₂ CO ₂ C ₂ H ₅	469
Butyl α -methyl α -cyano- succinate	NaOC ₂ H ₅	NCC(A) ₂ CONH ₂ (56) α -Isopropylglutaric acid++	282 783
Ethyl α , β -dicyano- β -methyl- succinate	[C ₆ H ₅ CH ₂ N(C ₂ H ₅) ₂]OH	C ₂ H ₅ O ₂ CCH(CH ₃)C(CN)(A)CO ₂ C ₂ H ₅ (94)	787
Diethyl α -cyano- β , β -dimethyl- glutarate	Not indicated	(CH ₃) ₂ C(CN)C(A)(CN)CO ₂ C ₂ H ₅ (89)	788, 789
Diethyl 3,4-dicyano-3-methyl- butane-1,4-dicarboxylate	[C ₆ H ₅ CH ₂ N(C ₂ H ₅) ₂]OH	C ₂ H ₅ O ₂ CCH ₂ C(CH ₃) ₂ C(A)(CN)CO ₂ C ₂ H ₅ (72)	790
		AC(CN)(CO ₂ C ₂ H ₅)C(CN)(CH ₃)CH ₂ CH ₂ CO ₂ C ₂ H ₅ (83)	791

Note: References 491-1045 are on pp. 545-555.

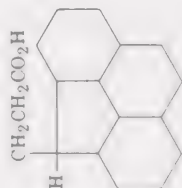
* Compare the review by Bruson.²⁷⁴

++ This product was isolated after saponification of the adduct.

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

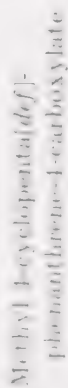
Reactants	Catalyst	Product (Yield, %)	References
<i>D. Esters and Amides (Cont.)</i>		$A = -CH_2CH_2CN$	
Ethyl phenylacrylate	KOH, CH_3OH	$C_6H_5C(A)(CN)(CO_2C_2H_5)$ (69–83)	792
Diethyl 1,2-dicyano-2-methylpentane-1,5-dicarboxylate	$[C_6H_5CH_2N(CH_3)_3]OH$	$C_2H_5O_2C(CH_2)_3C(CN)(CH_3)C(A)(CN)CO_2C_2H_5$ (99)	793
Methyl ethylphenylacetate	$NaOCH_3$	$(C_6H_5)(C_2H_5)C(A)CO_2CH_3$	794
Methyl <i>n</i> -propylphenylacetate	$NaOCH_3$	$(C_6H_5)(n-C_3H_7)C(A)CO_2CH_3$	794
Methyl <i>n</i> -butylphenylacetate	$NaOCH_3$	$(C_6H_5)(n-C_4H_9)C(A)CO_2CH_3$	794
Methyl isobutylphenylacetate	$NaOCH_3$	$C_6H_5(i-C_4H_9)C(A)CO_2CH_3$	794
Methyl diphenylacetate	$NaOCH_3$	$(C_6H_5)_2C(A)CO_2CH_3$	794
Methyl fluorene-9-carboxylate	KOH	9-Carbomethoxy-9-(β -cyanoethyl)fluorene (94)	795
Ethyl 1-methylfluorene-9-carboxylate	NaOH, pyridine	9-Carbomethoxy-9-(β -cyanoethyl)-1-methylfluorene (78)	482
Ethyl 2,7-dibromofluorene-9-carboxylate	$[C_6H_5CH_2N(CH_3)_3]OH$	9-Carbomethoxy-9-(β -cyanoethyl)-2,7-dibromofluorene (93)	796



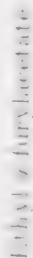
(90)





797



277



Phenyl isobutyrate	$\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3\text{OH}$ or OC_4H_9 <i>n</i>	 (32)	277
Ethyl 2-pyridylacetate	Na	 (72)	798
<i>E. Keto Esters and Amides</i>			
Methyl acetate	$\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3\text{OH}$	$\text{CH}_3\text{COC}(\text{CH}_3)(\text{A})\text{CO}_2\text{CH}_3$ (49)	760, 761
Ethyl acetate	$\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3\text{OH}$ or OC_4H_9 <i>n</i>	$\text{CH}_3\text{COC}(\text{CH}_3)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (79-80) or $\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (79-80)	277, 760, 761, 767
	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}_2\text{H}_5$	$\text{CH}_3\text{COC}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (83)	767
	NaOC_2H_5	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (40)	799
Ethyl methylacetate	KOH , CH_3OH , (CH_3) ₃ COH	$\text{CH}_3\text{COC}(\text{CH}_3)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (58, 57)	766, 800
	NaOC_2H_5	α -Methylglutaric acid (51) ^{††}	800
	—	$\text{CH}_3\text{COC}(\text{CH}_3)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (61)	782
Ethyl ethylacetate	KOH , CH_3OH , (CH_3) ₃ COH	$\text{CH}_3\text{COCH}(\text{A})\text{CH}_3$ (34) ^{††}	801
	—	$\text{CH}_3\text{COC}(\text{C}_2\text{H}_5)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (62)	800
	—	α -Ethylglutaric acid (62) ^{††}	800
Ethyl <i>n</i> -propylacetate	KOH , CH_3OH , (CH_3) ₃ COH	$\text{CH}_3\text{COCH}(\text{A})\text{CH}_2\text{CH}_3$ (43) ^{††}	801
	—	$\text{CH}_3\text{COC}(\text{C}_3\text{H}_7)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (88)	800
	—	α - <i>n</i> -Propylglutaric acid (88) ^{††}	800
	—	$\text{CH}_3\text{COCH}(\text{A})\text{CH}_2\text{CH}_2\text{CH}_3$ (36) ^{††}	801

Note: References 491-1045 are on pp. 545-555.




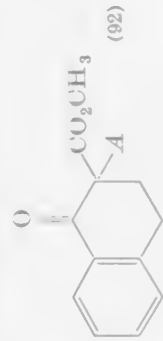
* Compare the review by Bruson.²⁷⁴

†† This product was isolated after saponification of the adduct.

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>E. Kato Esters and Amides (Cont.)</i>			
Ethyl isopropylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COCH(C ₃ H ₇ - <i>n</i>)(A)CO ₂ C ₂ H ₅ (37, 43)	591, 800
Ethyl allylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	α-Isopropylglutaric acid (43)†† CH ₃ COC(C ₃ H ₅)(A)CO ₂ C ₂ H ₅ (76)	800
Ethyl isobutylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	α-Allylglutaric acid (76)††	800
Ethyl isopropylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COCH(C ₄ H ₉ - <i>n</i>)(A)CO ₂ C ₂ H ₅ (74, 75)	119, 800
Ethyl isopropylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH; Na	α- <i>n</i> -Butylglutaric acid (75)†† CH ₃ COCH(A)CH ₂ CH ₂ CH ₂ CH ₃ (35)†† (CH ₃ COCH(C ₃ H ₁₁ - <i>n</i>)(A)CO ₂ C ₂ H ₅ (71)	801
Ethyl isopropylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	α- <i>n</i> -Amylglutaric acid (71)†† CH ₃ COCH(A)(CH ₂) ₄ CH ₃ (32)††	800
Ethyl isopropylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COC(C ₃ H ₁₁ - <i>i</i>)(A)CO ₂ C ₂ H ₅ (72)	801
Ethyl isopropylacetate	KOH, CH ₃ OH, (CH ₃) ₃ COH	α-Isoamylglutaric acid (72)††	800
Ethyl isopropylacetate	NaOC ₂ H ₅ ; KOH, CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COC(C ₆ H ₁₃ - <i>n</i>)(A)CO ₂ C ₂ H ₅ (84)	800
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	α- <i>n</i> -Hexylglutaric acid (84)††	800
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COC(C ₆ H ₅)(A)CO ₂ C ₂ H ₅ (27)	802
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COC(CH ₂ C ₆ H ₅)(A)CO ₂ C ₂ H ₅ (85)	581
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	CH ₃ COC(CH ₂ C ₆ H ₅)(A)CO ₂ C ₂ H ₅ (66)	800
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	α-Benzylglutaric acid (66)††	800
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	(CH ₃ COCH(A)CH ₂ C ₆ H ₅ (31)††	801
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	<i>n</i> -C ₃ H ₇ COCH(A)CO ₂ C ₂ H ₅ (34-36, 74)	217, 119
Ethyl isopropylacetate	NaOC ₂ H ₅ , CH ₃ OH, (CH ₃) ₃ COH	<i>n</i> -C ₃ H ₇ COCH(A)CO ₂ C ₂ H ₅ (52)	799

Allyl isobutyrylacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ or $\text{OC}_4\text{H}_9\text{-}n$ NaOC_2H_5	$(\text{CH}_3)_2\text{CHCOCH(A)}_2\text{CO}_2\text{C}_2\text{H}_5$ (65-68)	277
Allyl isobutyrylacetate	NaOC_2H_5	$(\text{CH}_3)_2\text{CHCOCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (53)	799
Allyl isobutyrylacetate	NaOC_2H_5	$i\text{-C}_4\text{H}_9\text{COCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (46)	799
Allyl isobutyrylacetate	NaOC_2H_5	$n\text{-C}_5\text{H}_{11}\text{COCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (38, 67)	799, 803
Allyl isobutyrylacetate	NaOC_2H_5	$n\text{-C}_6\text{H}_{13}\text{COCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (35)	799
Ethyl benzoylacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ or $\text{OC}_4\text{H}_9\text{-}n$ NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH(A)}_2\text{CO}_2\text{C}_2\text{H}_5$ (53)	277
Ethyl 2-benzoylacetate	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (86, 43)	581, 799
Ethyl 2-benzoylacetate	NaOC_2H_5	 $\text{COCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (37)	799
Ethyl 2-phenylacetate	NaOC_2H_5	 $\text{COCH(A)}\text{CO}_2\text{C}_2\text{H}_5$ (64)	799
2-Carbomethoxycyclohexanone	$\text{KOH, C}_2\text{H}_5\text{OH;}$ $\text{NaOC}_2\text{H}_5; \text{NaNH}_2;$ $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 $\text{CO}_2\text{C}_2\text{H}_5$ (85)	119, 121, 694
Methyl camphor-3-carboxylate	$\text{KOH, C}_2\text{H}_5\text{OH}$	3-Carbomethoxy-3-(β-cyanoethyl)camphor (78)	119
2-Carbomethoxy-1-tetralone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 CO_2CH_3 (92)	801

Note: References 491-1045 are on pp. 545-555.


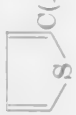
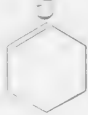
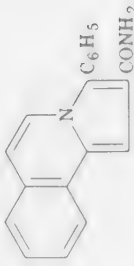
* Compare the review by Bruson.²⁷⁴

† This product was isolated after saponification of the adduct.

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*

Reactants	Catalyst	Product (Yield, %)	References
<i>E, Keto Esters and Amides (Cont.)</i>			
Acetoacetonitrile	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{COC}(\text{A})_2\text{CONHC}_6\text{H}_5$	760
Acetoacet-2-chloroanilide	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{COC}(\text{A})_2\text{CONHC}_6\text{H}_4\text{Cl-}o$	760
Acetoacet-2,5-dichloroanilide	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{COC}(\text{A})_2\text{CONHC}_6\text{H}_3\text{Cl}_2$ -2,5	760
Acetolactylolactone	NaOC_2H_5	2-Aceto-2-(β -cyanoethyl)butyrolactone (86-92)	581
<i>F. Nitriles</i>			
Allyl cyanide (or crotononitrile)	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{CH}=\text{C}(\text{A})\text{CN}$ (9)	283
		$\text{CH}_2=\text{CHC}(\text{A})_2\text{CN}$ (23)	
Isopropenyl cyanide (or β,β -dimethylacrylonitrile)	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(\text{CH}_3)_2\text{C}=\text{C}(\text{A})\text{CN}$ (5)	283
		$\text{CH}_2=\text{C}(\text{CH}_3)\text{C}(\text{A})_2\text{CN}$ (11)	469
Benzyl cyanide	Aq. NaCN	$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN}$ (80)	282
	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_6\text{H}_5\text{C}(\text{A})_2\text{CN}$ (94)	805
	NaOC_2H_5	$\text{C}_6\text{H}_5\text{C}(\text{A})_2\text{CN}$ (46)	767
	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$\text{C}_6\text{H}_5\text{C}(\text{A})_2\text{CN}$ (70)	767
	$[\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_3]\text{OC}_2\text{H}_5$	$\text{C}_6\text{H}_5\text{C}(\text{A})_2\text{CN}$ (90)	282
	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$p\text{-O}_2\text{NC}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (90)	806
	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$o\text{-ClC}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (47)	806
	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$m\text{-ClC}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (64)	806
	KOH	$p\text{-ClC}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (80)	807
p -Nitrobenzyl cyanide	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$m\text{-BrC}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (89)	806
o -Chlorobenzyl cyanide	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$p\text{-BrC}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (84)	806
m -Chlorobenzyl cyanide	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$m\text{-CH}_3\text{C}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (88)	806
p -Chlorobenzyl cyanide	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$p\text{-CH}_3\text{C}_6\text{H}_4\text{C}(\text{A})_2\text{CN}$ (95)	806
m -Bromobenzyl cyanide	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$	$(\text{C}_6\text{H}_5)(\text{CH}_3)\text{C}(\text{A})\text{CN}$ (55)	758
p -Bromobenzyl cyanide	$\text{KOH}, \text{CH}_3\text{OH}, (\text{CH}_3)_3\text{COH}$		
m -Methylbenzyl cyanide			
p -Methylbenzyl cyanide			
α -Phenylpropionitrile			

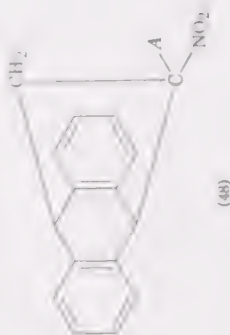
<i>p</i> -Isopropylbenzyl cyanide	KOH		$p\text{-(CH}_3)_2\text{CHC}_6\text{H}_4\text{CH}_2\text{CN}$	807
Cyclohexenylacetonitrile		$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 $\text{C(}A\text{)}_2\text{CN}$ (37)	283
2-Phenylbenzyl cyanide		$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 $\text{C(}A\text{)}(\text{C}_6\text{H}_5)\text{CN}$	808
2-Naphthylacetonitrile		$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\alpha\text{-C}_{10}\text{H}_7\text{C(}A\text{)}_2\text{CN}$ (55)	807
α -(1-Cyclohexenyl)benzyl cyanide		$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 $\text{C(}A\text{)}(\text{C}_6\text{H}_5)\text{CN}$	808
1-Cyano-2-benzoyl-1,2-dihydro- isquinoline	Li salt			805 <i>a</i>
<i>cf. Nitro Compounds</i>				
Nitromethane		NaOCH_3 ; aq. K_2CO_3 $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $(\text{C}_2\text{H}_5)_2\text{NH}$; NaOCH_3 Aq. K_2CO_3 Aq. KOH	$(A)_2\text{CHNO}_2$ (low); $(A)_3\text{CNO}_2$ (52) $(A)_3\text{CNO}_2$ (45) $\text{CH}_3\text{CH(A)NO}_2$ (30) $\text{CH}_3\text{C(A)}_2\text{NO}_2$ (67) $(\text{CH}_3)_2\text{C(A)NO}_2$ (78)	117, 281 282 117, 280 281
2-Nitropropane		Aq. KOH	1-Nitro-1-(β -cyanoethyl)cyclohexane (40)	117
Nitrocyclohexane		Aq. KOH	$(A)_2\text{C}(\text{NO}_2)_2$ (34); $(A)_3\text{CNO}_2$ (12)	117
$\text{O}_2\text{NCH=NO}_2\text{K}$		Aq. solution		809

Note: References 491-1045 are on pp. 545-555.

* Compare the review by Bruson.²⁷⁴

TABLE X—Continued

MICHAEL CONDENSATIONS WITH ACRYLONITRILE*			
Reactants	Catalyst	Product (Yield, %)	References
<i>G. Nitro Compounds (Cont.)</i>			
$(\text{CH}_3\text{O}_2\text{CCH}_2\text{CH}_2\text{C}(\text{NO}_2)=\text{NO}_2\text{Na})$	Aq. solution	$A(\text{NO}_2)_2(\text{CH}_2\text{CH}_2\text{CO}_2\text{CH}_3)$	810
<i>p</i> -Bromophenylbutyromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$p\text{-BrC}_6\text{H}_4\text{C}(A)_2\text{NO}_2$ (15)	117
Methyl 2-nitro-1-phenylpropyl ether	Aq. NaOH	3-Nitro-3-methyl-4-methoxy-4-phenylvaleronitrile (30)	117
<i>m</i> -Butyl 3-nitro- <i>m</i> -butyl sulfone	$(\text{CH}_3\text{N}(\text{C}_2\text{H}_5)_3)\text{OH}$	3-Nitro-3-methyl-5-(butylsulfonyl)-1-pentamethylnitrile	117
Ethyl nitroacetate	KOH, ethanol	Ethyl α -nitro- γ -cyanobutyrate (19)	811
	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{O}_2\text{NCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (52)	812
	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{O}_2\text{NC}(A)_2\text{CO}_2\text{C}_2\text{H}_5$ (80)	812
	Na derivative in water	$\text{O}_2\text{NCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (diethylamine salt) (81)	622
Methyl γ -dinitrobutyrate		Methyl 6-cyano-4,4-dinitrohexanoate (51)	810

NaOCH₃*1*-dimethylmethyleneanthracene

813

H Sulfones

Phenyl benzyl sulfone

Allyl *p*-tolyl sulfone $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ Phenyl *p*-chlorobenzyl sulfone^{¶¶}KOH, CH_3OH $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $\text{C}_6\text{H}_5\text{SO}_2\text{C}(\text{A})_2\text{C}_6\text{H}_5$ (60) $p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{CH}(\text{A})\text{CH}-\text{CH}_2$ and $p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{A})_2\text{CH}-\text{CH}_2$ $p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{C}(\text{A})_2\text{CO}_2\text{C}_2\text{H}_5$ $p\text{-ClC}_6\text{H}_4\text{C}(\text{A})_2\text{SO}_2\text{C}_6\text{H}_5$ (60)

279, 814

814

814

815

I. Phosphonoacetates

Triethyl phosphonoacetate

 $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ NaOC_2H_5

Na

K

 $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$

Diethyl cyanomethanephosphate

 $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{A})_2\text{CO}_2\text{C}_2\text{H}_5$ (87) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (28) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{A})_2\text{CO}_2\text{C}_2\text{H}_5$ (27) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (40) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{A})_2\text{CO}_2\text{C}_2\text{H}_5$ (19) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{A})_2\text{CO}_2\text{C}_2\text{H}_5$ (68) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{CN})(\text{A}_2)$ (90)

816

817

817

816

 $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{CN})(\text{A})_2$ (80) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{CH}_3)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (58) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{C}_4\text{H}_9\text{-}n)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (71) $(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{C}(\text{C}_4\text{H}_9\text{-}n)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (73)

817

124

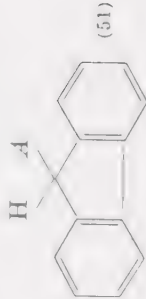

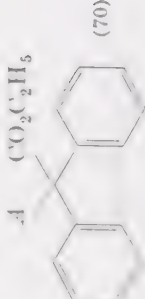
124

817

Note: References 491–1045 are on pp. 545–555.* Compare the review by Bruson.²⁷⁴¶¶ The ortho and meta isomers give analogous reactions. From *o*- and *m*-methyl benzylphenyl sulfone only undefined oils were formed; the para isomer failed to react.

TABLE XI

MICHAEL CONDENSATIONS WITH UNSATURATED NITRILES OTHER THAN ACRYLONITRILE

Reactants	Catalyst	Product (Yield, %)	References
<i>Crotononitrile (or Allyl Cyanide) and</i>		$A = \text{CH}_3\text{CHCH}_2\text{CN}$	
Ethyl cyanoacetate	NaOC_2H_5	$A\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (90)	77
Ethyl α -cyanopropionate	NaOC_2H_5	$\text{CH}_3\text{C}(A)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	77
Benzyl cyanide	NaOC_2H_5 ; NaOCH_3	$\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$ (76)	27
1-Nitropropane	Aq. NaOH	$\text{C}_2\text{H}_5\text{CH}(A)\text{NO}_2$ (80)	117
2-Nitropropane	$[\text{CH}_3\text{N}(\text{C}_2\text{H}_5)_3]\text{OH}$	$(\text{CH}_3)_2\text{C}(A)\text{NO}_2$ (80)	117
Fluorene	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 (51)	282
Methyl fluorene-9-carboxylate	KOH	 (73)	291
Ethyl fluorene-9-carboxylate	KOH	 (70)	291
<i>Methacrylonitrile and</i>			
1,2,3,4-Tetrahydrofluoranthene	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	1-(β -Cyanopropyl)-1,2,3,4-tetrahydrofluoranthene	754, 755

γ-Methoxycrotonitrile and

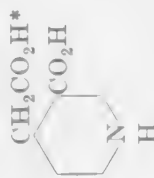
Diethyl malonate



Diethyl ethylmalonate

Diethyl *β*-methoxyethylmalonateDiethyl *β*-ethoxyethylmalonate*3-Cyano-1,2,5,6-tetrahydropyridine and*

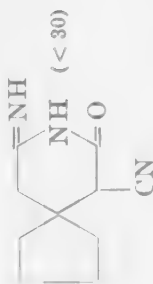
Diethyl malonate



(Cincholoiponic acid, 2 isomers)

Cyclopentylideneacetoneitrile and

Cyanoacetamide



(< 30)

1-Cyano-2-methyl-1-cyclohexene and

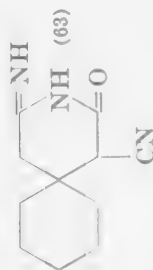
Diethyl malonate



Diethyl (2-cyano-1-methylcyclohexyl)malonate (low)

Cyclohexylideneacetoneitrile and

Cyanoacetamide



(63)

Note: References 491–1045 are on pp. 545–555.

* This product was obtained after hydrolysis and partial decarboxylation.

ACH(CO₂C₂H₅)₂ (74)AC(C₂H₅)(CO₂C₂H₅)₂ (36)AC(C₂H₅CH₂OCH₃)(CO₂C₂H₅)₂ (40–50)AC(C₂H₅CH₂OC₂H₅)(CO₂C₂H₅)₂ (42)

818, cf. 819

820

820

820

87

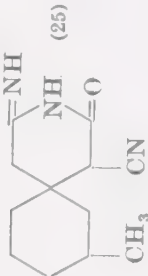
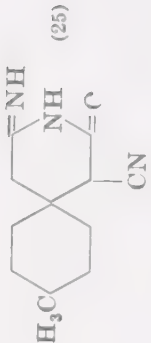
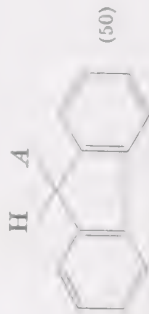
821

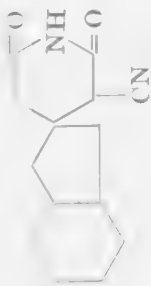

822

821

TABLE XI—Continued

MICHAEL CONDENSATIONS WITH UNSATURATED NITRILES OTHER THAN ACRYLONITRILE

Reactants	Catalyst	Product (Yield, %)	References
(3- <i>Methylcyclohexylidene</i>)acetonitrile and (Cyanooacetamide)	NaOC_2H_5	 (25)	402a
(4- <i>Methylcyclohexylidene</i>)acetonitrile and (Cyanooacetamide)	NaOC_2H_5	 (25)	402a
<i>Cinnamonnitrile</i> and Diethyl malonate Ethyl phenylacetate Benzyl cyanide <i>p</i> -Methoxybenzyl cyanide <i>m</i> -Aminobenzyl cyanide	NaOC_2H_5 NaOC_2H_5 ; NaOCH_3 NaOC_2H_5 ; NaOCH_3 NaOC_2H_5 ; NaOCH_3 NaOC_2H_5 ; NaOCH_3	$A = \text{C}_6\text{H}_5\text{CHCH}_2\text{CN}$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (83) $\text{C}_6\text{H}_5\text{CH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (50) $\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$ (80–87) $p\text{-CH}_3\text{OC}_6\text{H}_4\text{CH}(A)\text{CN}$ (23) $m\text{-H}_2\text{NC}_6\text{H}_4\text{CH}(A)\text{CN}$ (Two isomers: 17, 30)	290 27 27, 805 27 27
Fluorene	$(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH}$	 (50)	289

<i>p</i> -Methoxycinnamionitrile and Isobutyl cyanide	NaOC_2H_5 ; NaOCHH_3	$\text{C}_6\text{H}_5\text{CH}(\text{CN})\text{CH}(\text{C}_6\text{H}_4\text{OCH}_3\text{-}p)\text{CH}_2\text{CN}$ (72)	27
2-Hydrindanylideneacetoneitrile and Cyanacetamide	NaOC_2H_5	 and 	90
α -Phenylcinnamionitrile and Nitroethane Nitroethane	$(\text{C}_2\text{H}_5)_2\text{NH}$ $(\text{C}_2\text{H}_5)_2\text{NH}$	$A = \text{C}_6\text{H}_5\text{CHCH}(\text{C}_6\text{H}_5)\text{CN}$ $\text{A} = \text{C}_6\text{H}_5\text{CHCH}(\text{C}_6\text{H}_5)\text{CN}$ $\text{A} = \text{C}_6\text{H}_5\text{CHCH}(\text{C}_6\text{H}_5)\text{CN}$ $\text{A} = \text{C}_6\text{H}_5\text{CHCH}(\text{C}_6\text{H}_5)\text{CN}$	117 117
α -(<i>p</i> -Bromophenyl)cinnamionitrile and Nitroethane	Piperidine	$\text{C}_6\text{H}_5\text{CH}[\text{CH}(\text{CH}_3)\text{NO}_2]\text{CH}(\text{CN})\text{C}_6\text{H}_4\text{Br-}p$	117
1-Cyano-1,3-butadiene and Diethyl malonate Ethyl acetoacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$A = \text{---CH}_2\text{CH}=\text{CHCH}_2\text{CN}$ $(A)_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (13) $\text{CH}_3\text{COC}(A)_2\text{CO}_2\text{C}_2\text{H}_5$ (28)	91 91

Note: References 491-1045 are on pp. 545-555.

TABLE XI—Continued
MICHAEL CONDENSATIONS WITH UNSATURATED NITRILES OTHER THAN ACRYLONITRILE


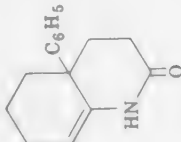
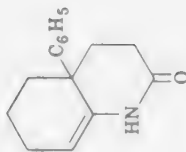
Reactants	Catalyst	Product (Yield, %)	References
1-Cyano-1,3-butadiene (Cont.) and			
Ethyl cyanoacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$A = -\text{CH}_2\text{CH}=\text{CHCH}_2\text{CN}$	91
Acetylacetone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(A)_2\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	91
Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(A)_2\text{C}(\text{COCH}_3)_2$ (22)	293
Nitroethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(A)_3\text{CNO}_2$	293
1-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{CH}(A)\text{NO}_2$ and $\text{CH}_3\text{C}(A)_2\text{NO}_2$ (total, 65)	293
2-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_2\text{H}_5\text{CH}(A)\text{NO}_2$ $(\text{CH}_3)_2\text{C}(A)\text{NO}_2$ (77)	293
Nitrocyclohexane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$		293

TABLE XI.4

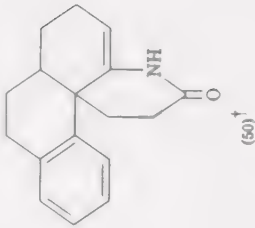
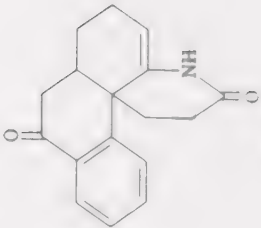
MICHAEL CONDENSATIONS WITH ACRYLAMIDE²⁸⁵ AND METHACRYLAMIDE^{8,23}

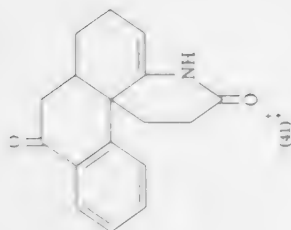
Reactants	Catalyst	Product (Yield, %)
<i>Acrylamide and</i>		
Cyclohexanone	NaH	2-Oxo-1,2,3,4,5,6,7,8-octahydroquinoline (10)
Acetylacetone	KOC ₄ H _{9-t}	γ -Benzoylbutyric acid* (20)
Dibenzyl ketone	KOC ₄ H _{9-t}	[C ₆ H ₅ CH(C ₆ H ₅)CH ₂ CONH ₂] ₂ CO (48)
2-Phenylcyclohexanone	KOC ₄ H _{9-t}	 (39)
2-Phenylcycloheptanone	NaNH ₂	 (29)
2-Phenylcycloheptanone	KOC ₄ H _{9-t} NaNH ₂	Lactam of β -(2-keto-1-phenylcycloheptyl)propionic acid (31) Lactam of β -(2-keto-1-phenylcycloheptyl)propionic acid (22)

* This product was obtained after hydrolysis.

TABLE XI.4—Continued

MICHAEL CONDENSATIONS WITH ACRYLAMIDE²⁹⁵ AND METHACRYLAMIDE⁴²³

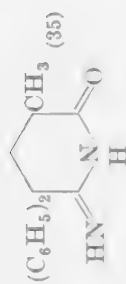
Reactants <i>Acrylamide (Cont.) and</i>	Catalyst	Product (Yield, %)
4-Oxo-1,2,3,4,9,10,11,12-octahydrophenanthrene	$\text{KOC}_4\text{H}_9\text{-}t$	 (50) [†]
4,9-Dioxo-1,2,3,4,9,10,11,12-octahydrophenanthrene	$\text{KOC}_4\text{H}_9\text{-}t$	 (22)



NaH

Methacrylamide and

Diphenylacetonitrile

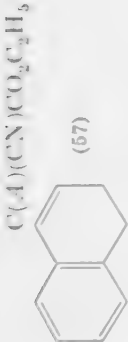
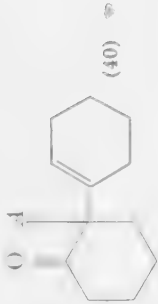
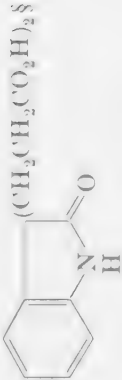
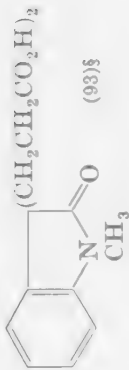
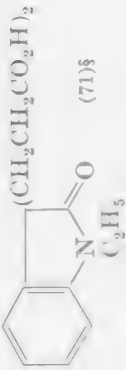
NaOC₂H₅

† The yield of lactam was 23%; when the residual reaction mixture was hydrolyzed, the yield of the corresponding acid was 27%.

‡ The yield of lactam was 57%; further work up of the mother liquor yielded an additional 16% of the lactam.

TABLE XII

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES				
Reactants	Catalyst	Product (Yield, %)	References	
<i>Methyl Acrylate and</i>				
Diethyl malonate	Na	$A = -CH_2CH_2CO_2CH_3$	$ACH(CO_2C_2H_5)_2$ (76)	525
Diethyl acetoacetaldehyde	$NaOC_2H_5$		Glutamic acid* (64)	463
Ethyl acetoacetate	$NaOC_2H_5$; Na		$CH_3COCH(A)CO_2C_2H_5$ (73, 38)	824, 525
Ethyl 5-oxo-3-oxopentanoate	Na		Methyl 5-oxo-6-heptenoate (19)†	538
Ethyl benzoylacetate	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5COCH(A)CO_2C_2H_5$ (52)	536
Ethyl cyanoacetate	$NaOC_2H_5$		$NCCH(A)CO_2C_2H_5$ (73)	825
Malononitrile	$[C_6H_5CH_2N(CH_3)_3]OH$		$(A)_2C(CN)_2$	826
Diethyl 1,2-dicyano-2-methylpentano-1,5-dicarboxylate	KOC_2H_5		$(A)C(CN)(CO_2C_2H_5)C(CN)(CH_3)CH_2CH_2CO_2C_2H_5$ (65)	793
Benzyl cyanide	$NaOCH_3$; $NaNH_2$		$C_6H_5CH(A)CN$ (20-24)	27
α -Phenylpropionitrile	$NaOCH_3$		$C_6H_5C(A)(CH_3)CN$ (43)	758
α -Phenylbutyronitrile	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_2H_5)CN$	808
α -Isopropylbenzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_3H_7-i)CN$	808
α -Isobutylbenzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_4H_9-i)CN$	808
α -2-Phenylbenzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_4H_3S)CN$	808
α - <i>n</i> -Pentylbenzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_5H_{11}-n)CN$	808
α -(3-Methylbutyl)benzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(CN)CH_2CH_2CH(CH_3)_2$	808
α -(2-Pyridyl)benzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_5H_4N)CN$	808
α -(2-Pyridyl)- <i>p</i> -chlorobenzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		<i>p</i> -Cl- $C_6H_4C(A)(C_5H_4N)CN$	808
α -(1-Cyclohexenyl)benzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_6H_9)CN$	808
α -Cyclohexylbenzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_6H_{11})CN$	808
Diphenylacetone nitrile	$NaOC_2H_5$		$(C_6H_5)_2C(A)CN$	823
α -(<i>p</i> -Chlorophenyl)benzyl cyanide	$[C_6H_5CH_2N(CH_3)_3]OH$		$C_6H_5C(A)(C_6H_4Cl-p)CN$	808

Ethyl (α -tetralylidene)cyanoacetate†	NaOC_2H_5		827
2-(1-Cyclohexenyl)cyclohexanone	$[\text{C}_6\text{H}_9\text{CH}_2\text{N}(\text{C}_6\text{H}_9)_3]\text{OCHH}_3$		828
Oxindole	NaOC_2H_5		829
1-Methyloxindole	NaOC_2H_5		372
1-Ethylloxindole	NaOC_2H_5		829

Note: References 491–1045 are on pp. 545–555.



* This acid was isolated after hydrolysis and partial decarboxylation.

† This compound was isolated by partial hydrolysis and decarboxylation, which were accompanied by elimination of one molecule of ethanol.

‡ This compound reacts in the tautomeric β,γ -unsaturated form.

§ This compound was isolated after saponification.

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Methyl Acrylate (Cont.) and</i>		$A = -CH_2CH_2CO_2CH_3$	
Methyl oxindole-3-propionate	$NaOC_2H_5$	 (66)§	829
Ethyl oxindole-3-propionate	$NaOC_2H_5$	 (17)§	372
Nitromethane	$[C_6H_5CH_2N(CH_3)_3]OH$	$(A)CH_2NO_2$ (35)	457, 830
Nitroethane	$[C_6H_5CH_2N(CH_3)_3]OH$; $(C_2H_5)_3N$	$(A)_2CHNO_2$	831
1-Nitropropane	$(C_2H_5)_3N$	$CH_3CH(A)NO_2$ (66)	832, 830,
2-Nitropropane	$(C_2H_5)_3N$		833
	$[C_6H_5CH_2N(CH_3)_3]OH$	$C_2H_5CH(A)NO_2$ (80)	832
		$(CH_3)_2C(A)NO_2$ (81)	832
		$(CH_3)_2C(A)NO_2$ (80-86)	830, 834,
1-Nitrobutane	$[C_6H_5CH_2N(CH_3)_3]OH$		835
2-Methyl-1-nitropropane	$[C_6H_5CH_2N(CH_3)_3]OH$	$n-C_3H_7CH(A)NO_2$ (51)	453
		$n-C_3H_7C(A)_2NO_2$ (36)	453
Dinitromethane	—	$(CH_3)_2CHCH(A)NO_2$ (59)	
<i>Di-n-Dinitroethanol</i>	—	$(CH_3)_2CHC(A)_2NO_2$ (9)	809
		$(A)_2C(NO_2)_2$ (60)	809, 810,
		$(A)C(NO_2)_2CH_2OH$ (20)	836, 837
Methyl 3,3-dinitrobutyrate	—¶	$4C(NO_2)_2CH_2CH_2CO_2CH_3$ (45)	810

Methyl <i>n</i> -isopropyl nitro- butyrate	$(C_2H_5)_2NH$	$(CH_3)_2CHC(A)_2NO_2$ (41)	453
	$C_6H_5CH_2N(C_2H_5)_3$ OH	$(CH_3)_2CHC(A)_2NO_2$ (20)	
<i>trans</i> -1,2-ethylenedioxyanthracene	$NaOCH_3$		813
Triethyl phosphonoacetate	$NaOC_2H_5$ Na (small amount) K (molar amount)	$(C_2H_5O)_2P(O)CH(A)(CO_2C_2H_5)$ (40) $(C_2H_5O)_2P(O)CH(A)(CO_2C_2H_5)$ (53) $(C_2H_5O)_2P(O)C(A)CO_2C_2H_5$ (67)	124 817 817
Triethyl α -phosphonohexanoate	$NaOC_2H_5$ K (molar amount)	$(C_2H_5O)_2P(O)C(A)(C_4H_9-n)CO_2C_2H_5$ (64) $(C_2H_5O)_2P(O)C(A)(C_4H_9-n)(CO_2C_2H_5)$ (73)	124 817
Diethyl malonate	$NaOC_2H_5$ Anion exchange resin	$ACH(CO_2C_2H_5)_2$ $ACH(CO_2C_2H_5)_2$; $(A)_2C(CO_2C_2H_5)_2$ $AC(C_2H_5)(CO_2C_2H_5)_2$ (74)	66 480 66
Diethyl methylmalonate	$NaOC_2H_5$	$AC(C_2H_5)(CO_2C_2H_5)_2$ (79)	838
Diethyl ethylmalonate**	$NaOC_2H_5$	$AC(C_4H_9-n)(CO_2C_2H_5)_2$ (88)	838
Diethyl <i>n</i> -butylmalonate††	$NaOC_2H_5$	$AC(C_6H_{13-n})(CO_2C_2H_5)_2$ (83)	838
Diethyl <i>n</i> -hexylmalonate***	$NaOC_2H_5$	$AC(C_8H_{17-n})(CO_2C_2H_5)_2$ (81)	838
Diethyl <i>n</i> -octylmalonate***	$NaOC_2H_5$	$AC(C_{10}H_{21-n})(CO_2C_2H_5)_2$ (79)	838
Diethyl <i>n</i> -decylmalonate***	$NaOC_2H_5$		

Note: References 491-1045 are on pp. 545-555.

§ This compound was isolated after saponification.


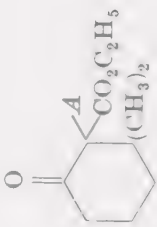
• The dinitro compound was used as its potassium salt in aqueous solution; no other catalyst was employed.


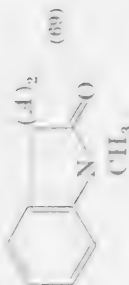
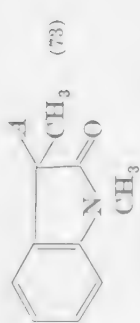
• The dinitro compound was employed as its *ac*i-sodium salt in aqueous solution.

*** In this experiment methyl acrylate was used as starting material; it was *trans*-esterified by the catalyst solution.

†† When methyl acrylate and sodium ethoxide were employed, an 85% yield of n - $C_4H_9C(A)(CO_2C_2H_5)_2$ was obtained.

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Acrylate and</i>			
Diethyl <i>n</i> -dodecylmalonate**	NaOC ₂ H ₅	A = —CH ₂ CH ₂ CO ₂ C ₂ H ₅ AC(C ₁₂ H _{25-n})(CO ₂ C ₂ H ₅) ₂ (80) AC(C ₁₄ H _{29-n})(CO ₂ C ₂ H ₅) ₂ (80) AC(C ₁₆ H _{33-n})(CO ₂ C ₂ H ₅) ₂ (83)	838
Diethyl <i>n</i> -tetradecylmalonate**	NaOC ₂ H ₅		838
Diethyl <i>n</i> -hexadecylmalonate**	NaOC ₂ H ₅		838
Ethyl 1-methyl-1,2,5,6-tetra- hydropyridine-4-acetate	NaH	CH(A)CO ₂ C ₂ H ₅  (69)	467
Ethyl acetoacetate	NaOC ₂ H ₅ ; NaOH	CH ₃ COCH(A)CO ₂ C ₂ H ₅ (80, 67)	839, 119, 30
2-Carbethoxy-3,3-dimethyl- cyclohexanone	NaOC ₂ H ₅	 (49)	840
Ethyl cyanoacetate	NaOC ₂ H ₅	ACH(CN)CO ₂ C ₂ H ₅	841, 842††
Cyanoacetamide	Na deriv.	3-(gamma-2,6-dioxopiperidine	843
Cyclohexane-1,3-dione	NaOC ₂ H ₅	Diethyl 3-(beta-carbethoxyethyl)-4-oxoheptane-1,7- dicarboxylate (64)§§	844
2-Ethylcyclohexane-1,3-dione	NaOC ₂ H ₅	Diethyl 3-ethyl-4-oxoheptane-1,7-dicarboxylate (61)§§	844
2-Allylcyclohexane-1,3-dione	NaOC ₂ H ₅	Diethyl 3-allyl-4-oxoheptane-1,7-dicarboxylate (66)§§	771
2-Benzylcyclohexane-1,3-dione	NaOC ₂ H ₅	Diethyl 3-benzyl-4-oxoheptane-1,7-dicarboxylate (61)§§	844

Oxindole	NaOC_2H_5		845
1-Methyloxindole	NaOC_2H_5		846
1,3-Dimethyloxindole	NaOC_2H_5		846
Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(\text{A})_2\text{CHNO}_2$	452
Nitroethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{ACH}(\text{CH}_3)\text{NO}_2$ (60) or $(\text{A})_2\text{C}(\text{CH}_3)\text{NO}_2$	830, 452
1-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_2\text{H}_5\text{CH}(\text{A})\text{NO}_2$	830
2-Nitropropane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_2\text{H}_5\text{C}(\text{A})_2\text{NO}_2$	830
<i>n</i> -Butyl nitroethanol	—	$(\text{CH}_3)_2\text{C}(\text{A})\text{NO}_2$	830
Ethyl nitroacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(\text{NO}_2)_2\text{C}(\text{A})\text{CH}_2\text{OH}$ (35)	837
		$\text{ACH}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5$ (55)	455
		$\text{A}_2\text{C}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5$ (22)	455
		$\text{ACH}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5$ (11)	811
	$[\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{ACH}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5$	847

Note: References 491–1015 are on pp. 545–555.



The indiro compound was used as its potassium salt in aqueous solution; no other catalyst was employed.

†† In this experiment methyl acrylate was used as starting material; it was *trans*-esterified by the catalyst solution.

‡‡ In this experiment, the condensation product was not isolated, but was treated directly with ethyl α -bromoisobutyrate.

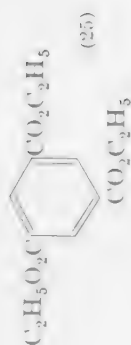
§§ This product is formed by hydrolytic fission of the cyclohexane ring.

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Acrylate (Cont.) and</i>			
Ethyl β -methyl- γ -nitrobutyrate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ (<i>i</i> - C_3H_7) ₂ NH	$A = -\text{CH}_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ $A\text{CH}(\text{NO}_2)\text{CH}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (63) $A\text{CH}(\text{NO}_2)\text{CH}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (46)	456 456
Ethyl γ -nitro β - <i>n</i> -propylbutyrate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$A\text{CH}(\text{NO}_2)\text{CH}(\text{C}_3\text{H}_7\text{-}n)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (53)	116
Ethyl γ -acetoxy- β -nitromethylbutyrate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$A\text{CH}(\text{NO}_2)\text{CH}(\text{CH}_2\text{OCOCH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (67)	457
Ethyl β -nitroisopropylmalonate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$A\text{CH}(\text{NO}_2)\text{CH}(\text{CH}_3)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (65)	457
2-Benzoyl-1-cyano-1,2-dihydro-isoquinoline	Li salt	 (58) $\text{CH}_2\text{CH}(\text{COC}_6\text{H}_5)(\text{COC}_2\text{H}_5)$	805a
<i>n</i> -Butyl Acrylate and			
Methyl β -cyanoethyl ketone	Aq. KCN	$A = -\text{CH}_2\text{CH}_2\text{CO}_2\text{C}_4\text{H}_9\text{-}n$ $\text{CH}_3\text{COCH}(A)\text{CH}_2\text{CN}$ and $\text{CH}_3\text{COC}(A)_2\text{CH}_2\text{CN}$	123
<i>o,p</i> -Dinitroethanol	—	$\text{AC}(\text{NO}_2)_2\text{CH}_2\text{OH}$ (23)	837
γ -Hydroxycrotonolactone and			
Ethyl γ -ethoxyacetate	Na	 $\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)\text{COCH}_2\text{OC}_2\text{H}_5$	848
<i>Ethyl beta-Hydroxyacrylate and</i>			
Nitromethane	Enolate	Ethyl β -hydroxy- γ -nitrobutyrate (quant.)	546
Nitroethane	Enolate	Ethyl β -hydroxy- γ -nitropentanoate (66)	546
1-Nitropropane	Enolate	Ethyl β -hydroxy- γ -nitrohexanoate (54)	546

Ethyl β-Ethoxyacrylate and

Diethyl malonate

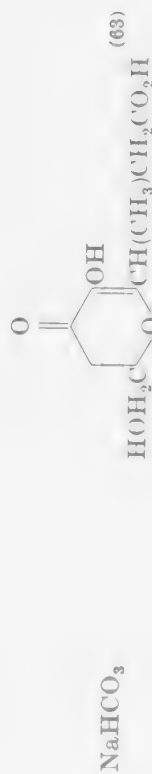
 $[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}_2\text{H}_5$ 

Diethyl methylmalonate

$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}_2\text{H}_5$ Diethyl 3-ethoxybutane-2,4-dicarboxylate (19) and diethyl carbonate; diethyl 1-butene-1,3-dicarboxylate (18) 307

*Crotonic Acid and*

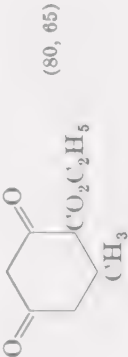
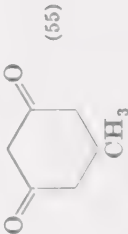

Kojic acid

*Note:* References 491–1045 are on pp. 545–555.


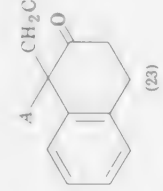

|| The dinitro compound was used as its potassium salt in aqueous solution; no other catalyst was employed.

TABLE XII—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Crotonate and</i> Diethyl malonate	NaOC_2H_5	$A = -\text{CH}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (38, 53, 95, 98)	5, 851, 50, 850, 7, 8 50, cf. 607
Diethyl methylmalonate	NaOC_2H_5 (1/6 mole)	2-Methylbutane-1,3,3-tricarboxylic acid§ and 2-methylbutane-1,1,3-tricarboxylic acid§ (9 : 1, 90)	
Ethyl phenylacetate	NaOC_2H_5 (1 mole)	2-Methylbutane-1,1,3-tricarboxylic acid§ (60)	50, cf. 607
Ethyl 3,4-dimethoxyphenyl- acetate	K NaOC_2H_5	$\text{C}_6\text{H}_5\text{CH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (22) 3,4-(CH_3O) $_2\text{C}_6\text{H}_3\text{CH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (76)	852 853
Ethyl acetoacetate	NaOC_2H_5	$\text{CH}_3\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (60)	782
		 (80, 65)	180, 854
		 (55)	855
2-Carboethoxycyclopentanone	KOC_2H_5		856, 857, 858

triethyl 2-methylhexane-1,3,6-tricarboxylate§§

2-Carboethoxy-5-methylcyclopentanone	KOC_2H_5		(66)	859, 860
Ethyl cyanoacetate	NaOC_2H_5	$\text{ACH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ ¶		77, 80
Ethyl α -cyanopropionate	NaOC_2H_5	$\text{CH}_3\text{C}(\text{A})(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (50)		77
Ethyl α -cyanobutyrate	NaOC_2H_5	$\text{C}_2\text{H}_5\text{C}(\text{A})(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (33)		80
Ethyl α -cyanohydrocinnamate	NaOC_2H_5	$\text{C}_6\text{H}_5\text{CH}_2\text{C}(\text{A})(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$		349
Cyanoacetamide	Na enolate	3-Cyano-2,6-dioxo-4-methylpiperidine		27
Benzyl cyanide	NaOC_2H_5	$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN}$ (63-68)		
1-(β -Diethylaminoethyl)-2-tetralone	NaOC_2H_5		(23)	861
Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_2]\text{OC}_4\text{H}_9$ $(\text{C}_2\text{H}_5)_2\text{NH}$	ACH_2NO_2 (55)		456
	$i\text{-C}_3\text{H}_7)_2\text{NH}$	ACH_2NO_2 (15)		456
Triethyl phosphonoacetate	K	ACH_2NO_2 (25)		456
		$(\text{C}_2\text{H}_5\text{O})_2\text{P}(\text{O})\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (66)		817
Ethyl α -Chlorocrotonate and Ethyl acetoacetate	Na enolate			862

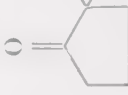
Note: References 491-1045 are on pp. 545-555.

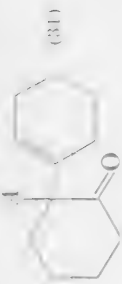

§ This compound was isolated after saponification.

§§ This product is formed by hydrolytic fission of the alicyclic ring.

¶¶ This product has not been isolated, but was condensed with ethyl β -chloropropionate (ref. 859) or ethyl bromoacetate (ref. 860).

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl β-Hydroxycrotonate and</i> Cyanacetamide	Piperidine	3-Cyano-6-hydroxy-4-methyl-2-pyridone	378
<i>Ethyl β-Aminocrotonate and</i> Malonoamide	Piperidine	6-Hydroxy-4-methyl-2-pyridone-3-carboxamide	378
Cyanoacetamide	Piperidine	3-Cyano-6-hydroxy-4-methyl-2-pyridone	391
<i>Ethyl β-Ethoxycrotonate and</i> Cyanacetamide	Piperidine	3-Cyano-6-hydroxy-4-methyl-2-pyridone	378
<i>Ethyl γ-Acetoxycrotonate and</i> Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}_4\text{H}_9$	$\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}(\text{CH}_2\text{NO}_2)(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$ (65)	457
<i>Ethyl γ,γ-Trifluorocrotonate and</i> Nitromethane	$(\text{C}_2\text{H}_5)_3\text{N}$	$\text{CF}_3\text{CH}(\text{CH}_2\text{NO}_2)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (68)	863
<i>Methyl Methacrylate and</i> Diethyl methylmalonate	NaOC_2H_5 NaOC_2H_5	$A = -\text{CH}_2\text{CH}(\text{CH}_3)\text{CO}_2\text{CH}_3$ Triethyl pentane-2,2,4-tricarboxylate (66) $\text{CH}_3\text{COCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CH}(\text{CH}_3)\text{CO}_2\text{CH}_3$	864 782
2-Carboethoxycyclopentane	NaOCH_3	 (70)	865
Propenylacetamide	NaOOC_2H_5	$(\text{C}_6\text{H}_5)_2\text{C}(\text{A})\text{CN}$ (80)	823

2,3-Cyclohexenyl cyclohexanone	$(C_6H_5)_2CH_2N(CH_2)_3OCH_3$	 (31)	828
2-Nitropropane	$(C_2H_5)_2NH$	$(CH_3)_2C(A)NO_2$ (35)	832
Diethyl phosphonoacetate	$NaOC_2H_5$	$(C_2H_5O)_2P(O)CH(CO_2C_2H_5)CH_2CH(CH_3)CO_2CH_3$ (42)	124
Diethyl 3-phosphohexanoate	$NaOC_2H_5$	$(C_2H_5O)_2P(O)C(C_4H_9)(CO_2C_2H_5)CH_2CH(CH_3)CO_2CH_3$ (75)	124
<i>Ethyl Methacrylate and</i>		$A = -CH_2CH(CH_3)CO_2C_2H_5$	
Diethyl methylmalonate	$NaOC_2H_5$	$AC(CH_3)(CO_2C_2H_5)_2$	866
Ethyl acetate	$NaOC_2H_5$	$CH_3COCH(A)CO_2C_2H_5$ (24)	867
Ethyl isobutyrate	$NaOC_2H_5$	$CH_3CH(CO_2C_2H_5)CH_2CH(CO_2C_2H_5)CH(CH_3)_2$	320
2-Carboxycyclopentanone*** K		 (17)	865
Ethyl cyanoacetate	Na; $NaOC_2H_5$	$ACH(CN)CO_2C_2H_5$	78, cf. 866
<i>Ethyl β-Hydroxymethacrylate and</i>			
Malonic acid	Pyridine, piperidine	<i>trans</i> -α-Methylglutamic acid (47)*	366, 868
Cyanoacetic acid	Pyridine, piperidine	Ethyl 4-cyano-2-methyl-2-butenoate	366
Nitromethane	Ester enolate	Ethyl α-methyl-β-hydroxy-γ-nitrobutyrate	546
<i>Dimethyl Methylenemalonate and</i>			
o-Nitrophenylacetic acid	Na	3,3-Dicarbomethoxy-1-(o-nitrophenyl)butyric acid (58)	869

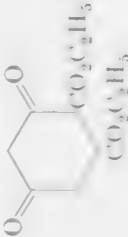

Note: References 491–1045 are on pp. 545–555.

* This acid was isolated after hydrolysis and partial decarboxylation.

*** The ethyl methacrylate was formed *in situ* from ethyl α-bromoisobutyrate.

TABLE XII—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES			
Reactants	Catalyst	Product (Yield, %)	References
<i>Diethyl Methylene-malonate</i> ††† and			
Diethyl malonate	KOH, C_2H_5OH	$(C_2H_5O_2C)_2CHCH_2CH(CO_2C_2H_5)_2$ (quant.)	870
Tetraethyl propane-1,1,3,3-tetracarboxylate	KOH, C_2H_5OH	Hexaethyl pentane-1,1,3,3,5,5-hexacarboxylate	870
Ethyl <i>o</i> -nitrophenylacetate	$NaOC_2H_5$	$o-O_2NC_6H_4CH(CO_2C_2H_5)CH_2CH(CO_2C_2H_5)_2$ (60)	871, 829, 872
Ethyl acetoacetate	$NaOC_2H_5$	Triethyl 2-oxopentane-3,5,5-tricarboxylate (38)	867
<i>Dimethyl Maleate</i> and			
Diethyl <i>n</i> -butylmalonate	Not indicated	$n-C_4H_9CH(CO_2H)CH(CO_2H)CH_2CO_2H^*$	873
Diethyl isobutylmalonate	Not indicated	$i-C_5H_{11}CH(CO_2H)CH(CO_2H)CH_2CO_2H^*$	873
Diethyl <i>n</i> -hexylmalonate	Not indicated	$n-C_6H_{13}CH(CO_2H)CH(CO_2H)CH_2CO_2H^*$	873
Diethyl cyclohexylmalonate	Not indicated	$C_6H_{11}CH(CO_2H)CH(CO_2H)CH_2CO_2H^*$	873
Diethyl isoöctylmalonate	Not indicated	$i-C_8H_{17}CH(CO_2H)CH(CO_2H)CH_2CO_2H^*$	873
Benzyl cyanide	$NaOCH_3$	$C_6H_5CH(CN)CH(CO_2CH_3)CH_2CO_2CH_3$ (50)	27
<i>Dimethyl Maleate</i> and			
2-Nitropropane†††	$(C_2H_5)_2NH \cdot CH_3CO_2H$	$(CH_3)_2C(NO_2)CH(CO_2CH_3)CH_2CO_2CH_3$ (69)	832
	C_2H_5NH	$(CH_3)_2C(NO_2)CH(CO_2CH_3)CH_2CO_2CH_3$ (80); $(CH_3)_2C=C(CO_2CH_3)CH_2CO_2CH_3$ (16)	832
	$(C_2H_5)_2NH$	$(CH_3)_2C(NO_2)CH(CO_2CH_3)CH_2CO_2CH_3$ (85)	832
Triethyl phosphonoacetate	$NaOC_2H_5$	$(C_2H_5O)_2P(O)CH(CO_2C_2H_5)CH(CO_2CH_3)CH_2CO_2CH_3$ (13)	124
<i>Diethyl Maleate</i> and			
Diethyl malonate	Na; KOH, acetal	$A = -CH(CO_2C_2H_5)CH_2CO_2C_2H_5$ $ACH(CO_2C_2H_5)_2$ (72)	483, 6, 517, 518

Triethyl phenylacetate	NaOC_2H_5 KOH, acetal	$\text{C}_6\text{H}_5\text{CH}(A)\text{CO}_2\text{C}_2\text{H}_5$ ($\text{C}_6\text{H}_5\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (72))	874 48
	Na; NaOC_2H_5		316, 875
2-Carboethoxycyclopentanone	Piperidine		876
Benzyl cyanide	KOC_2H_5 NaOCH_3 ; NaOC_2H_5 KOH, acetal	Tetraethyl hexane-1,2,3,4-tetracarboxylate (96) §§ $\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$ (52-58) $\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$ (74)	876 27 483, 517,
2-Methylcyclohexane-1,3-dione	NaOC_2H_5	Triethyl 3-methyl-4-oxoheptane-1,2,7-tricarboxylate (62) §§	518 844
<i>Dimethyl Fumarate and</i>		$A = -\text{CH}(\text{CO}_2\text{CH}_3)\text{CH}_2\text{CO}_2\text{CH}_3$	
Diethyl malonate	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{ACh}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (5)	18
Ethyl cyanoacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{ACh}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (10)	18
2-Nitropropane	$(\text{C}_2\text{H}_5)_2\text{NH}$; $(\text{C}_2\text{H}_5)_3\text{N}$	$(\text{CH}_3)_2\text{C}(A)\text{NO}_2$ (80-85)	832

Note: References 491-1045 are on pp. 545-555.

* This acid was isolated after hydrolysis and partial decarboxylation.

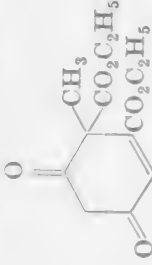
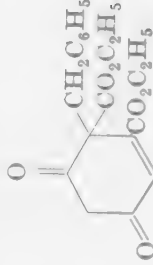
§§ This product is formed by hydrolytic fission of the alicyclic ring.

+++ Instead of the unsaturated ester, dimethyl methoxymethylmalonate was employed.

+++ The reaction involves the preliminary isomerization of diethyl maleate to diethyl fumarate.

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Diethyl Fumarate (Cont.) and</i> Diethyl malonate	Na; NaOC ₂ H ₅	$A = -CH(CO_2C_2H_5)CH_2CO_2C_2H_5$ $ACH(CO_2C_2H_5)_2$ (90, 55)	77, 5, 7, 8, 6, 877, 878
Diethyl methylmalonate	NaOC ₂ H ₅	$AC(CH_3)(CO_2C_2H_5)_2$	77, 878, 7, 8
Diethyl ethylmalonate	NaOC ₂ H ₅	$AC(C_2H_5)(CO_2C_2H_5)_2$ (61, 80)	5, 879, 7, 8, 77, 878
Diethyl isopropylmalonate	NaOC ₂ H ₅	$AC(C_3H_7-i)(CO_2C_2H_5)_2$	7, 878
Diethyl benzylmalonate	NaOC ₂ H ₅	$AC(CH_2C_6H_5)(CO_2C_2H_5)_2$ (23-31) §§	56, 880
Ethyl acetoacetate	Na; NaOC ₂ H ₅	$CH_3COCH(A)CO_2C_2H_5$ and <div> </div>	875
Ethyl methylacetoacetate	NaOC ₂ H ₅	$CH_3COC(CH_3)(A)CO_2C_2H_5$ and <div> </div>	316, 878
Ethyl ethylacetoacetate	NaOC ₂ H ₅	$CH_3COC(C_2H_5)(A)CO_2C_2H_5$	875
Ethyl propionylacetoacetate	NaOC ₂ H ₅	$C_2H_5COC(A)(CO_2C_2H_5)_2$	879
Ethyl benzylacetoacetate	NaOC ₂ H ₅	$CH_3COC(CH_2C_6H_5)(A)(CO_2C_2H_5)_2$	875
Ethyl cyanacetoacetate	Na	$NCCH(A)CO_2H$; $NCCH(A)CO_2C_2H_5$	316
Benzyl cyanide	NaOC ₂ H ₅	$C_6H_5CH(CN)C(=O)C(=O)C(=O)C_6H_5$ <div> </div>	881

2 Nitropropane	$(C_2H_5)_2NH$ (0.2 mole) $(C_2H_5)_2NH$ (1.25 mole)	$(CH_3)_2C(NO_2)_2$ (90) $(CH_3)_2C-C(CO_2C_2H_5)(CH_2CO_2C_2H_5)$ (83)	832 832
<i>Diethyl Chloroformate and</i> Ethyl acetate	$NaOC_2H_5$	$CH_3COC(CO_2C_2H_5)=C(CO_2C_2H_5)CH_2CO_2C_2H_5$	882-885
Ethyl methylacetate	$NaOC_2H_5$	 (21)	882, 883 885, 862
Ethyl benzylacetate	$NaOC_2H_5$		862

Note: References 491-1045 are on pp. 545-555.

§§§ Gardner and Rydon (refs. 58-61) have ascribed to the product the isomeric structure $C_8H_5CH_2CH(CO_2C_2H_5)CH(CO_2C_2H_5)CH_2CO_2C_2H_5$.

§§§ The formula

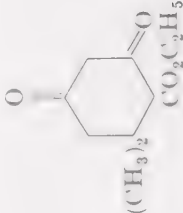


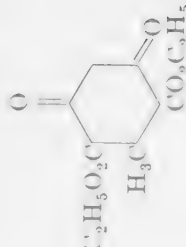
originally (refs. 882-883) assumed has been proven incorrect.

§§§ By analogy with the behavior of ethyl methylacetate, this formula is more probable than the one originally suggested:



TABLE XII—Continued

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl β,β-Dimethylacrylate and Diethyl malonate</i>	KOC ₂ H ₅ ; NaOC ₂ H ₅	$A = (\text{CH}_3)_2\text{CCH}_2\text{CO}_2\text{C}_2\text{H}_5$ $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2 \text{ (35)}$	886, 11, 24
<i>Ethyl acetoacetate</i>	Na		415
<i>Ethyl α-cyanopropionate Benzyl cyanide</i>	Na NaOC ₂ H ₅	$\text{CH}_3\text{C}(\text{A})(\text{CN})\text{CO}_2\text{C}_2\text{H}_5^{****}$ $\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN} \text{ (43)}$	23 27
<i>Ethyl Tiglate and Diethyl malonate</i>	NaOC ₂ H ₅	$A = -\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$ $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2 \text{ (15, 63)}$	50, 59, cf. 887
<i>Diethyl ethylmalonate Ethyl phenylacetate Ethyl cyanoacetate</i>	NaOC ₂ H ₅ K Na enolate	$\text{AC}(\text{C}_2\text{H}_5)(\text{CO}_2\text{C}_2\text{H}_5)_2 \text{ (14)}$ $\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ $A\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5 \text{ (42, 65)}$	59 852 50, 887, 888
<i>Ethyl α-Ethylacrylate and Ethyl acetoacetate</i>	NaOC ₂ H ₅	$\text{CH}_3\text{C}\text{OCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CH}(\text{C}_2\text{H}_5)\text{CO}_2\text{C}_2\text{H}_5 \text{ (20),}$ <p style="text-align: center;">diethyl α-ethylglutarate</p>	889

<i>Dimethyl Glutaconate and</i>					
Methyl cyanoacetate	NaOCH ₃	$A = -CH(CH_2CO_2CH_3)_2$	$A = -CH(CH_2CO_2CH_3)_2$		890
Ethyl cyanoacetate	Na; NaOCH ₃ ; NaOC ₂ H ₅	$A = -CH(CN)CO_2CH_3$ (46)	$A = -CH(CN)CO_2CH_3$ (64)		890, 392
Nitromethane	$[C_6H_5CH_2N(CH_3)_3]OH$	$A = -CH_2NO_2$ (51)			891
<i>Dimethyl Ethyldienemalonate and</i>					
Deoxybenzoin	NaOCH ₃	$C_6H_5COCH(C_6H_5)CH(CH_3)CH_2CO_2H$ (55)*			163
<i>Diethyl Ethyldienemalonate and</i>					
Diethyl malonate††††	None; Na	$A = CH_3CHCH(CO_2C_2H_5)_2$	$A = CH_3CHCH(CO_2C_2H_5)_2$		892, 893
Ethyl acetoacetate	NaOC ₂ H ₅				14
Nitromethane	$[C_6H_5CH_2N(CH_3)_3]OH$	$A = CH_2NO_2$ (69)			457
<i>Ethyl Ethyldienemalonate†††† and</i>					
Ethyl malonamate	KOH; $(C_2H_5)_2NH$	$CH_3CH[CH(CO_2C_2H_5)CONH_2]_2$ (73)			895

Note: References 491–1045 are on pp. 545–555.

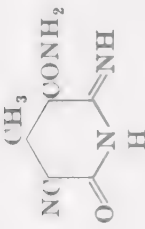
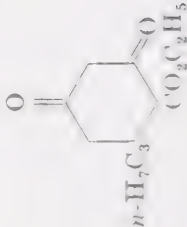
* This acid was isolated after hydrolysis and partial decarboxylation.

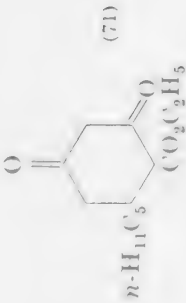
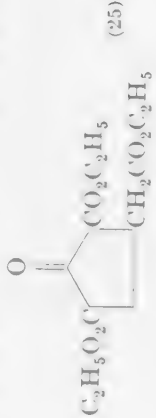
**** The product has not been isolated, but has been methylated directly.

†††† The same reaction takes place when acetaldehyde and diethyl malonate react in the presence of secondary amines; the yield is from 11 (ref. 887) to 55% (ref. 894).

††††† This material is formed *in situ* from the aldehyde or ketone and the derivative of malonic or cyanoacetic acid.

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethylidenecyanoacetamide</i> ††††† and Cyanoacetamide	KOH	$\text{CH}_3\text{CH}[\text{CH}(\text{CONH}_2)(\text{CN})]_2$, 	896
<i>Ethylidenemalononitrile</i> ††††† and Malononitrile	Piperidine	$\text{CH}_3\text{CH}[\text{CH}(\text{CN})]_2$	897
<i>Ethyl α-Ethylcrotonate</i> and Diethyl malonate	NaOC_2H_5	$A = \text{CH}_3\text{CHCH}(\text{C}_2\text{H}_5)(\text{CO}_2\text{C}_2\text{H}_5)$	59
Diethyl ethylmalonate	NaOC_2H_5	$A\text{C}(\text{C}_2\text{H}_5)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (39)	59
Ethyl cyanoacetate	NaOC_2H_5	$A\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (60)	77
<i>Ethyl β-n-Propylacrylate</i> and Ethyl acetoacetate	NaOC_2H_5		898
Nitromethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OC}_2\text{H}_5$	$n\text{-C}_3\text{H}_7\text{CH}(\text{CH}_2\text{NO}_2)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (71)	116
<i>Ethyl β-Isopropylacrylate</i> and Triethyl malonate	NaOC_2H_5	$i\text{-C}_3\text{H}_7\text{CH}(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	886

<i>Ethyl α-n-Butylacrylate and Ethyl cyanoacetate</i>	NaOC_2H_5	$(\text{N}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CH}(\text{C}_4\text{H}_9-n)(\text{CO}_2\text{C}_2\text{H}_5) \quad (54)$	889
<i>Methyl β-n-Pentylacrylate and Ethyl acetate</i>	NaOC_2H_5	 <p style="text-align: center;">(71)</p>	180
<i>Dimethyl 1,2-Dihydromuconate and Ethyl cyanoacetate</i>	NaOC_2H_5	$(\beta\text{-Carboxymethyl})_2\text{adipic acid (79)*}$	899
<i>Ethyl phenethylcyanoacetate</i>	KOC_2H_5	$(\text{C}_6\text{H}_5(\text{CH}_2\text{CH}_2(\text{CN})(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)-\text{CH}_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5) \quad (46)$	899
<i>Diethyl 1,2-Dihydromuconate and Diethyl malonate</i>	NaOC_2H_5	$(\text{C}_2\text{H}_5\text{O}_2(\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2) \quad (50),$	900
<i>Ethyl 4,4,5,5,6,6-Heptafluoro-2-hexenoate and Nitromethane</i>	$(\text{C}_2\text{H}_5)_3\text{N}$	 <p style="text-align: center;">(25)</p>	900
<i>Diethyl Propylidenemalonate and Diethyl malonate</i>	Enolate	$\text{C}_2\text{H}_5\text{CH}[\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2]_2 \quad (\text{quant.})$	901

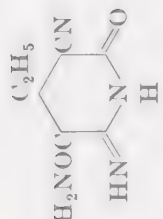
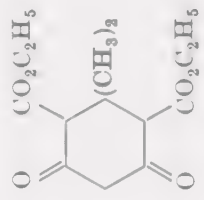
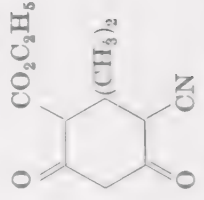

Note: References 491-1045 are on pp. 545-555.

* This acid was isolated after hydrolysis and partial decarboxylation.

++++ This material is formed *in situ* from the aldehyde or ketone and the derivative of malonic or cyanoacetic acid.

TABLE XII—Continued

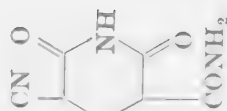
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Propylidenecyanoacetamide</i> †††† and <i>Cyanoacetamide</i>	KOH	$\text{C}_2\text{H}_5\text{CH}[\text{CH}(\text{CONH}_2)(\text{CN})]_2 \quad \text{and} \quad \text{H}_2\text{NOC}(\text{CN})\text{CH}_2\text{CN}$ 	896
<i>Diethyl Isopropylidenemalonate</i> and <i>Diethyl malonate</i>	NaOC_2H_5 ; enolate	$(\text{CH}_3)_2\text{C}[\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)]_2$ (95, 30, 8.	901, 902, 903, 904 905, 415
<i>Ethyl acetoacetate</i>	NaOC_2H_5	$\text{CH}_3\text{COCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{C}(\text{CH}_3)_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ 	
<i>Cyanoacetone</i> §§§§	NaOC_2H_5		415
<i>Acetylacetone</i>	NaOC_2H_5		415

$(\text{C}_2\text{H}_5)_2[\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5]_2$ (10) 906
 β,β -Dimethylglutarimide (quant.) 821
 Ethyl α -cyano- β,β -dimethyl- γ -nitrobutyrate (74) 907

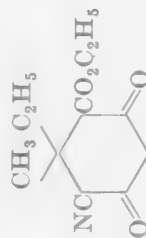
$(\text{C}_2\text{H}_5)_2\text{CH}(\text{CH}_2\text{OC}_2\text{H}_5)\text{CH}(\text{CH}_2\text{OC}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (79) 908

$(\text{C}_2\text{H}_5)_2\text{CH}[\text{CH}(\text{OC}_2\text{H}_5)_2]\text{CH}(\text{CH}_2\text{OC}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (48) 909



$n\text{-C}_3\text{H}_7\text{CH}[\text{CH}(\text{CN})\text{CONH}_2]_2$ and $n\text{-H}_7\text{C}_3$ 896

$(\text{CH}_3)_2\text{CHCH}[\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)]_2$ (41) 894



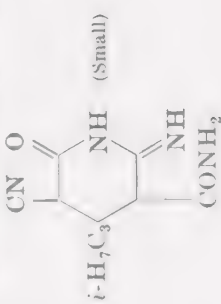



Ethyl acetoacetate NaOC_2H_5 415



Note: References 491–1045 are on pp. 545–555.

This material is formed *in situ* from the aldehyde or ketone and the derivative of malonic or cyanoacetic acid.
 Instead of cyanoacetone, α -methylisoxazole was employed.

TABLE XII—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Isobutyldenecyanoacetamide</i> †††† and cyanoacetamide	$(C_2H_5)_2NH$	$(CH_3)_2CHCH[CH(CN)CONH_2]_2$ (79)	910
			
<i>Diethyl Itaconate and</i> diethyl malonate	$NaOC_2H_5$	$A = -CH_2CH(CO_2C_2H_5)CH_2CO_2C_2H_5$ $4CH(CO_2C_2H_5)_2$, triethyl cyclopentanone-2,3,5-tri- carboxylate, ethyl cyclopentanone-3-carboxylate, diethyl cyclopentanone-2,4- (or 2,3-) dicarboxylate, 	8, 317, 911, 912
<i>Diethyl malonate</i>	$NaOC_2H_5$		
<i>Diethyl malonate</i>	$NaOC_2H_5$		317, 406

Tetraethyl 1,1,2,3-butanetetra-carboxylate 	NaOC_2H_5		911
Ethyl acetoacetate	NaOC_2H_5	$\text{CH}_3\text{COCH(A)CO}_2\text{C}_2\text{H}_5$	316
2-Carboxycyclopentanone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 (90 crude)	913
Ethyl cyanoacetate 	NaOC_2H_5	$\text{A}(\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5)$	316
Nitromethane	$(\text{C}_2\text{H}_5)_2\text{NH};$ $(i\text{-C}_3\text{H}_7)_2\text{NH}$	$\text{A}(\text{CH}_2\text{NO}_2)$ (25)	891
Nitroethane	$(i\text{-C}_3\text{H}_7)_2\text{NH}$	$\text{CH}_3\text{CH(A)NO}_2$ (40)	891
<i>Diethyl Mesaconate and</i> Diethyl malonate	NaOC_2H_5	$\text{C}_2\text{H}_5\text{O}_2\text{CCH}(\text{CH}_3)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (60-75)	6, 317
<i>Diethyl Citraconate and</i> Diethyl malonate	Na enolate NaOC_2H_5 NaOC_2H_5	$\text{C}_2\text{H}_5\text{O}_2\text{CCH}_2\text{C}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (72) $\text{C}_2\text{H}_5\text{O}_2\text{CCH}_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (50)  2,3,5-Tricarboethoxycyclopent anone	316, 317 316 316




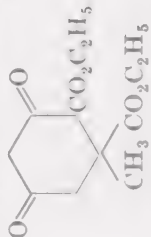
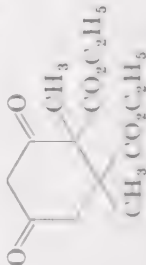
Note: References 491-1045 are on pp. 545-555.

**** This material is formed *in situ* from the aldehyde or ketone and the derivative of malonic or cyanoacetic acid.

*** Instead of diethyl itaconate, diethyl citraconate, which isomerizes under the conditions of the experiment, was employed.

 The citraconate is isomerized to itaconate.

TABLE XII—Continued

MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES			
Reactants	Catalyst	Product (Yield, %)	References
<i>Diethyl Citraconate (Cont.) and</i> <i>Diethyl malonate (Cont.)</i>	NaOC_2H_5	Diethyl itaconate, diethyl mesaconate, 3-carbethoxycyclopentanone, 2,3-(or 3,4-)dicarboethoxycyclopentanone, 2,3,5-tricarboethoxycyclopentanone, $\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$  	317, 912; cf. 5, 6, 8, 911
Diethyl ethylmalonate	Na enolate		5
Ethyl acetoacetate	Na; dry NaOC_2H_5	$\text{CH}_3\text{COCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{C}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$; 	316
Ethyl methylacetoacetate	Na	$\text{CH}_3\text{COCH}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)\text{C}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$; 	316

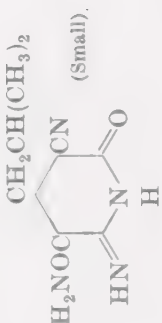
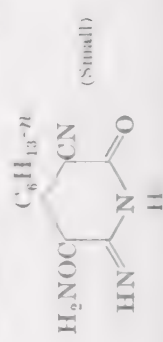
NaOC ₂ H ₅	$\text{CH}_3\text{COO}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)(\text{CH}_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)-\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5, \text{¶¶¶¶})$	316
Ethyl cyanoacetate	NCCH(CO ₂ C ₂ H ₅)C(C ₂ H ₅)(CO ₂ C ₂ H ₅)CH ₂ CO ₂ C ₂ H ₅ NCCH ₂ CH ₂ CH(CO ₂ C ₂ H ₅)(CH ₂ CO ₂ C ₂ H ₅)¶¶¶¶	316 316
<i>Trimethyl Aconitate***** and</i>	$A = \text{CH}_3\text{O}_2\text{CCH}_2\text{CH}(\text{CO}_2\text{CH}_3)\text{CHCO}_2\text{CH}_3$ $\text{ACH}(\text{CO}_2\text{CH}_3)_2$ $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ $\text{ACH}_3\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$	914 914 914
<i>Triethyl Aconitate and</i>		
Diethyl malonate		
Diethyl malonate		
Ethyl acetoacetate		
Diethyl malonate	Dry NaOC ₂ H ₅	915, 878
Ethyl acetoacetate	Na	7, 9, 10
	Na enolate	875
	Diethyl α-cyanoglutaconate and diethyl malonate	916
	Tetraethyl ethylenedisglutaconate	916a

Note: References 491–1045 are on pp. 545–555.

***** Trimethyl chlorotricarballylate was employed instead of trimethyl aconitate.

¶¶¶¶ The citraconate is isomerized to itaconate.

TABLE XII—Continued
MICHAEL CONDENSATIONS WITH ALIPHATIC α,β -ETHYLENIC ACID DERIVATIVES

Reactants	Catalyst	Product (Yield, %)	References
<i>Diethyl Isoamylidenemalonate</i> ††††† and Diethyl malonate	Na enolate; piperidine; (C_2H_5) ₂ NH	<i>i</i> - $C_4H_9CH[CH(CO_2C_2H_5)_2]_2$ (63)	894, 878, 917, 918
<i>Isoamylidenecyanoacetic Acid</i> ††††† and Cyanoacetic acid	Piperidine	α,α' -Dicyano- β -isobutylglutaric acid	917
<i>Isoamylidenecyanoacetamide</i> ††††† and Cyanacetamide	(C_2H_5) ₂ NH		910
<i>Ethyl (3-Pentylidene)cyanoacetate</i> ††††† and Ethyl cyanoacetate	NH_3	β,β -Diethylglutarimide (quant.)	821
<i>Diethyl Heptylidenemalonate</i> ††††† and Diethyl malonate	Piperidine; (C_2H_5) ₂ NH	<i>n</i> - $C_6H_{13}CH[CH(CO_2C_2H_5)_2]_2$	894
<i>Heptylidenecyanoacetic Acid</i> ††††† and Cyanoacetic acid	Piperidine	<i>n</i> - $C_6H_{13}CH[CH(CN)(CO_2H)]_2$	917
<i>Heptylidenecyanoacetamide</i> ††††† and Cyanacetamide	Piperidine	<i>n</i> - $C_6H_{13}CH[CH(CN)(CONH_2)]_2$ (87), 	910

<i>Triethyl Ethylenetetracarboxylate and</i>			
Diethyl malonate	NaOC_2H_5	$(\text{C}_2\text{H}_5\text{O}_2\text{C})_2\text{CHCH}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	878, 919
<i>Triethyl 1-Propylene-1,1,2-tricarboxylate and</i>			
Diethyl malonate	Na enolate	$(\text{C}_2\text{H}_5\text{O}_2\text{C})_2\text{CHCH}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (43-49)	920
<i>Triethyl 1-Propylene-2,3,3-tricarboxylate and</i>			
Diethyl malonate	Na enolate	$(\text{C}_2\text{H}_5\text{O}_2\text{C})_2\text{CHCH}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (61)	920
<i>Tetraethyl Ethylenetetracarboxylate and</i>			
Diethyl malonate	Na	Tricarballic acid*	893, 878
<i>Tetraethyl 1-Propylene-1,1,3,3-tetracarboxylate and</i>			
Ethyl cyanoacetate	Piperidine	Diethyl γ -carbethoxy- α -cyanoglutaconate and diethyl malonate	921
	NaOC_2H_5	Diethyl γ -carbethoxy- α -cyanoglutaconate, diethyl malonate, and diethyl α,γ -dicyanoglutarate	916
<i>Triethyl 3-Cyano-1-propylene-1,1,3-tricarboxylate and</i>			
Ethyl cyanoacetate	NaOC_2H_5	Diethyl α,γ -dicyanoglutaconate and diethyl malonate	916
<i>Tetraethyl 1-Butene-1,1,3,3-tetracarboxylate and</i>			
Ethyl cyanoacetate	NaOC_2H_5	Diethyl γ -carbethoxy- α -cyanoglutaconate and diethyl methylmalonate	916

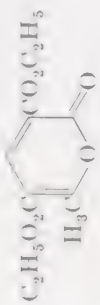
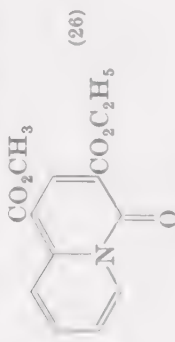
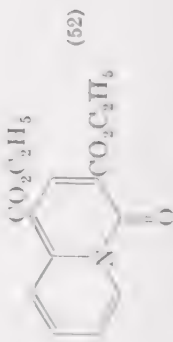
Note: References 491-1095 are on pp. 545-555.

* This acid was isolated after hydrolysis and partial decarboxylation.

†††† This material is formed *in situ* from the aldehyde or ketone and the derivative of malonic or cyanoacetic acid.

TABLE XIII

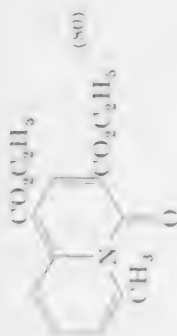
MICHAEL CONDENSATIONS WITH ETHYL ETHOXYMETHYLENOCYANOACETATE, DIETHYL ETHOXYMETHYLENEMALONATE, AND DIETHYL AMINOMETHYLENEMALONATE

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Ethoxymethylenecyanoacetate and</i>			
Ethyl acetacetate	NaOC_2H_5		310
<i>Diethyl Ethoxymethylenemalonate and</i>			
Diethyl malonate	NaOC_2H_5	$(\text{C}_2\text{H}_5\text{O}_2\text{C})_2\text{C}=\text{CHCH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	922
Ethyl phenylacetate	NaOC_2H_5	Diethyl 1-hydroxynaphthalene-2,4-dicarboxylate*	308
Ethyl <i>p</i> -chlorophenylacetate	NaOC_2H_5	Diethyl 7-chloro-1-hydroxynaphthalene-2,4-dicarboxylate* (7) and α -(<i>p</i> -chlorophenyl)glutaconic acid (11)†	309
Ethyl <i>p</i> -bromophenylacetate	NaOC_2H_5	Diethyl 7-bromo-1-hydroxynaphthalene-2,4-dicarboxylate* (11) and 7-bromo-1-hydroxynaphthalene-2,4-dicarboxylic acid (13)†	309
Ethyl α -naphthylacetate	NaOC_2H_5	1-Hydroxynaphthalene-2,4-dicarboxylic acid (5)† and α -(1-naphthyl)glutaconic acid†	309
<i>Methyl 2-pyridylacetate</i>			
Methyl 2-pyridylacetate	None		923
<i>Ethyl 2-pyridylacetate</i>			
Ethyl 2-pyridylacetate	None		923

924

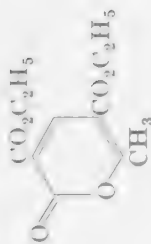
Ethyl 6-methyl-2-pyridylacetate

None



310

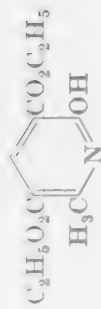
Ethyl acetoacetate

NaOC₂H₅

441

Ethyl β-aminocrotonate

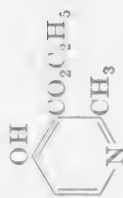
None

*Diethyl 2-Aminoethylene-1,1-dicarboxylate and*

441

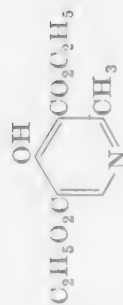
Ethyl acetoacetate

HCl



441

Na enolate

*Note:* References 491-1045 are on pp. 545-555.

* This compound could be isolated only after distillation of the crude condensation product. Direct hydrolysis of this product proved that it consisted of diethyl α-carbomethoxy-γ-phenylglutamate, C₆H₅O₂CCH(C₆H₅)CH=C(CO₂C₂H₅)₂.

† This acid was present in the crude product in the form of its ester, but was not isolated as such.

TABLE XIV

MICHAEL CONDENSATIONS WITH ALIPHATIC DIENIC AND TRIENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Methyl 1,3-Butadiene-1-carboxylate and</i> Dimethyl malonate Ethyl α -cyanopropionate	NaOCH_3 ; Na NaOCH_3 (1/8 mole)	$A = -\text{CH}_2\text{CH}=\text{CHCH}_2\text{CO}_2\text{CH}_3$ $A\text{CH}(\text{CO}_2\text{CH}_3)_2$ (75) $(\text{CH}_3\text{C}(A)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	397, 925, 926 926
<i>Methyl Sorbate and</i>		$A = \text{CH}_3\text{CHCH}=\text{CHCH}_2\text{CO}_2\text{CH}_3$ 	
Dimethyl malonate	NaOCH_3	$A\text{CH}(\text{CO}_2\text{CH}_3)_2$ and $\text{CH}_3\text{CH}=\text{CHCHCH}_2\text{CO}_2\text{CH}_3$ $\text{CH}(\text{CO}_2\text{CH}_3)_2$ (Mixture 9 : 1; 60-70, 80)	925-926, 927, 173
Ethyl α -cyanopropionate Nitromethane Methyl γ -nitrobutyrate	NaOCH_3 (1/8 mole) $(i\text{-C}_3\text{H}_7)_2\text{NH}$ $(i\text{-C}_3\text{H}_7)_2\text{NH}$	$A\text{C}(\text{CH}_3)(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (60-70) $A\text{CH}_2\text{NO}_2$ (21) $\text{O}_2\text{NCH}(A)\text{CH}_2\text{CH}_2\text{CO}_2\text{CH}_3$ (32)	926 116 116
<i>Ethyl Sorbate and</i> Diethyl malonate Ethyl cyanoacetate	Na NaOC_2H_5	$\text{HO}_2\text{CCH}_2\text{CH}=\text{CHCH}(\text{CH}_3)\text{CO}_2\text{H}^*$ $\text{CH}_3\text{CHCH}=\text{CHCH}_2\text{CO}_2\text{C}_2\text{H}_5$ $\text{CH}(\text{CN})(\text{CO}_2\text{C}_2\text{H}_5)$ (77) and $\text{CH}_3\text{CH}=\text{CHCHCH}_2\text{CO}_2\text{C}_2\text{H}_5$ $\text{CH}(\text{CN})(\text{CO}_2\text{C}_2\text{H}_5)$ (9)	928 397

Ethyl acetate	KOC_2H_5	$\begin{array}{c} \text{CH}_3\text{CHCH}=\text{CHCH}_2\text{CO}_2\text{C}_2\text{H}_5 \\ \\ \text{CH}(\text{COCH}_3)\text{CO}_2\text{C}_2\text{H}_5 \end{array} \quad (75)$	488
Ethyl α -Methylisorbate and Ethyl cyanoacetate	NaOC_2H_5	$\begin{array}{c} \text{CH}_3\text{CHCH}=\text{CHCH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5 \\ \\ \text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5 \end{array} \quad (67)$	397
Ethyl β -Methylisorbate and Diethyl malonate	NaOC_2H_5	$\begin{array}{c} \text{CH}_3\text{CHCH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5 \\ \\ \text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2 \end{array}$ <p style="text-align: center;">and</p> $\begin{array}{c} \text{CH}_3\text{CH}=\text{CHC}(\text{CH}_3)(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5) \\ \\ \text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2 \end{array}$ <p style="text-align: center;">(Mixture 9 : 1 ; 39-42)</p>	173
Ethyl cyanoacetate	NaOC_2H_5	$\begin{array}{c} \text{CH}_3\text{CHCH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5 \\ \\ \text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5 \end{array}$ <p style="text-align: center;">and</p> $\begin{array}{c} \text{CH}_3\text{CH}=\text{CHC}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5 \\ \\ \text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5 \end{array} \quad (65)$	397

Note: References 491-1045 are on pp. 545-555.

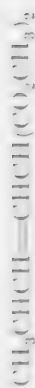
* This product was obtained after hydrolysis and partial decarboxylation.

TABLE XIV—Continued

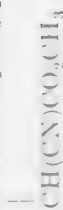
MICHAEL CONDENSATIONS WITH ALIPHATIC DIENIC AND TRIENIC ESTERS			References
Reactants	Catalyst	Product (Yield, %)	
<i>Ethyl γ-Methylsorbale and</i> Ethyl cyanoacetate	NaOC ₂ H ₅	$\text{CH}_3\text{CHC}(\text{CH}_3)=\text{CHCH}_2\text{CO}_2\text{C}_2\text{H}_5$ $\quad \quad \quad $ $\quad \quad \quad \text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ <p style="text-align: center;">and</p> $\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{CHCH}_2\text{CO}_2\text{C}_2\text{H}_5$ $\quad \quad \quad $ $\quad \quad \quad \text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ <p style="text-align: center;">(Mixture 1:3; 18–40)</p>	173
<i>Methyl Hexa-1,3,5-triene-1-carboxylate and</i> Dimethyl malonate	NaOC ₂ H ₅	Mixture of isomers of the formula C ₁₃ H ₁₈ O ₆ (44)	929
<i>Methyl Hepta-1,3,5-triene-1-carboxylate and</i> Dimethyl malonate	NaOCH ₃	$\text{CH}_3\text{CHCH}=\text{CHCH}=\text{CHCH}_2\text{CO}_2\text{CH}_3$ $\quad \quad \quad $ $\quad \quad \quad \text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ <p style="text-align: center;">and</p> $\text{CH}_3\text{CH}=\text{CHCH}=\text{CHCHCH}_2\text{CO}_2\text{CH}_3$ $\quad \quad \quad $ $\quad \quad \quad \text{CH}(\text{CO}_2\text{CH}_3)_2$ <p style="text-align: center;">(Mixture 7:1; 74)</p>	930

Dimethyl Pent-1,3-diene 1,1-dicyanoborate and
Methyl cyanoacetate

379



and



Methyl α -Cyanoethoxy- δ -methylsorbate and

Dimethyl malonate

NaOCH₃

381

Diethyl Muconate and

Diethyl malonate

Na



931, 326

NaOC₂H₅ (small
quant.)



932

Ethyl cyanoacetate




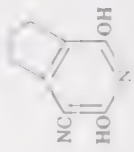
NaOC₂H₅

326

Note: References 491-1045 are on pp. 545-555.

TABLE XV

MICHAEL CONDENSATIONS WITH ALICYCLIC α,β -ETHYLENIC ESTERS

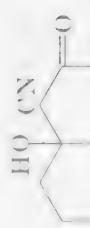
Reactants	Catalyst	Product (Yield, %)	References
<i>Methyl 1-Cyclobutene-1-carboxylate and</i>			
Diethyl malonate	$\text{KOC}_4\text{H}_9\text{-}t$	Diethyl (2-carbomethoxycyclobutyl)malonate (54)	933
Ethyl cyanoacetate	$\text{KOC}_4\text{H}_9\text{-}t$	Ethyl (2-carbomethoxycyclobutyl)cyanoacetate (52)	933
<i>Methyl 3,3-Dimethyl-1-cyclobutene-1-carboxylate and</i>			
Diethyl malonate	$\text{KOC}_4\text{H}_9\text{-}t$	Diethyl (4-carbomethoxy-2,2-dimethylcyclobutyl)malonate (57)	933
Ethyl cyanoacetate	$\text{KOC}_4\text{H}_9\text{-}t$	Ethyl (4-carbomethoxy-2,2-dimethylcyclobutyl)cyanoacetate (9)	933
<i>Ethyl 1-Cyclopentene-1-carboxylate and</i>			
		$A = $ 	
Diethyl malonate	NaOC_2H_5	$A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (80-85)	92
Ethyl acetoacetate	NaOC_2H_5	$A\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$ (23), $\text{CH}_3\text{COCH(A)CO}_2\text{C}_2\text{H}_5$ (8)	93
Ethyl cyanoacetate	NaOC_2H_5	$A\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (30-35)	92, 934, 935
			
<i>Ethyl 2-Hydroxy-1-cyclopentene-1-carboxylate and</i>			
Ethyl cyanoacetate	Piperidine; KOC_2H_5	 (50, 59)	936
Cyanoacetamide	Piperidine		937

Ethyl 1-Cyclohexene-1-carboxylate and

Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (40)	59, 938
Diethyl methylmalonate	NaOC_2H_5	$\text{AC}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (6)	59
Ethyl cyanoacetate	NaOC_2H_5 ; KOC_2H_5 ; piperidine	$\text{ACH}(\text{CN})(\text{CO}_2\text{C}_2\text{H}_5)$ (74, 35, 18)	939
	NaOC_2H_5	$\text{AC}(\text{CN})(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5^*$	940

Ethyl 2-Hydroxycyclohexene-1-carboxylate and

Cyanoacetamide	Pyridine		398
----------------	----------	--	-----

			941
--	--	--	-----


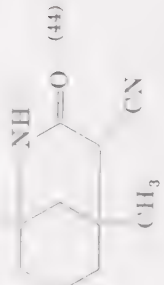
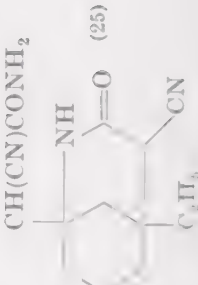
Ethyl 2-Aminocyclohexene-1-carboxylate and

Cyanoacetamide	None	4-Cyano-1-hydroxy-3-oxo-2,3,5,6,7,8-hexahydroisoquinoline	398
Malonamide	Piperidine	1-Hydroxy-3-oxo-2,3,5,6,7,8-hexahydroisoquinoline-4-carboxamide	391

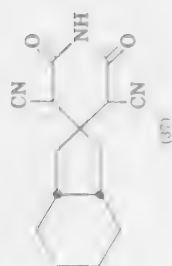
Note: References 491-1045 are on pp. 545-555.

* This compound was obtained by direct treatment of the condensation product with ethyl bromoacetate.

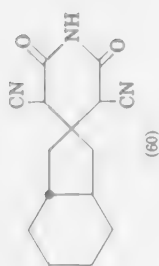
TABLE XV—Continued

MICHAEL CONDENSATIONS WITH ALICYCLIC α,β -ETHYLENIC ESTERS			References
Reactants	Catalyst	Product (Yield, %)	
<i>Ethyl 4-Methyl-1-cyclohexene-1-carboxylate and Ethyl cyanoacetate</i>	NaOC_2H_5	Ethyl 1-carbethoxy-4-methylcyclohexane-2-cyanoacetate†	942
<i>Ethyl (3-Methylcyclopentylidene)cynoacetate‡ and Ethyl cyanoacetate</i>	NH_3	 (50)	943
<i>Ethyl Cyclohexylidenecyanoacetate‡ and Ethyl cyanoacetate</i>	NaOC_2H_5	Cyclohexane-1,1-diacetic acid	221
<i>Ethyl (3-Methyl-2-cyclohexenylidene)cynoacetate‡ and Ethyl cyanoacetate</i>	NH_3	 (44)	649
<i>Ethyl (3-Ethyl-2-cyclohexenylidene)cynoacetate‡ and Ethyl cyanoacetate</i>	NH_3	 (25)	649

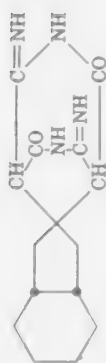
90



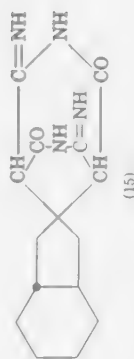
90



90



90



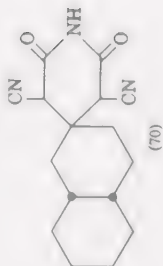
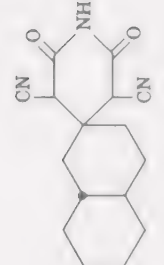
Note: References 491-1045 are on pp. 545-555.

† This product was directly condensed further with ethyl bromoacetate or ethyl β -chloropropionate.

‡ This compound was formed *in situ* from ethyl cyanoacetate and the corresponding ketone.

§ This compound was formed *in situ* from cyanoacetamide and the corresponding ketone.



TABLE XV—Continued
MICHAEL CONDENSATIONS WITH ALICYCLIC α,β -ETHYLENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl (cis-2-Decalylidene)cynoacetate</i>			
<i>Ethyl cyanoacetate</i>	NH_3	 (70)	944
<i>Ethyl (trans-2-Decalylidene)cynoacetate</i>			
<i>Ethyl cyanoacetate</i>	NH_3		944

Note: References 491–1045 are on pp. 545–555.

When this compound was formed *in situ* from ethyl cyanoacetate and *trans*-2-decalone, a 60% yield of the same condensation product was obtained.

TABLE XVI
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl 2-Furylacetate and</i> Diethyl malonate	NaOC_2H_5	 (49)	945
<i>Ethyl (4-Pyridyl)acrylate and</i> Diethyl malonate	NaOC_2H_5	 (94)	946
<i>Methyl Cinnamate and</i> Benzyl cyanide	KOC_2H_5 Dry NaOC_2H_5	$\text{C}_6\text{H}_5\text{CH}(\text{CH}_2\text{CO}_2\text{CH}_3)\text{CH}(\text{C}_6\text{H}_5)\text{CN}$ (59)	83
Acetophenone	NaNH_2	$\text{C}_6\text{H}_5\text{CH}(\text{CH}_2\text{CO}_2\text{CH}_3)\text{CH}(\text{C}_6\text{H}_5)\text{CN}$ $(\text{C}_6\text{H}_5\text{CH}(\text{CH}_2\text{CO}_2\text{H})\text{CH}_2\text{COC}_6\text{H}_5)$ (49)*	83 327

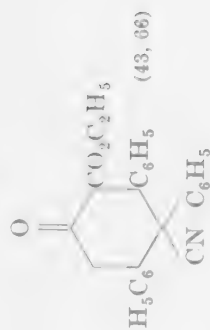
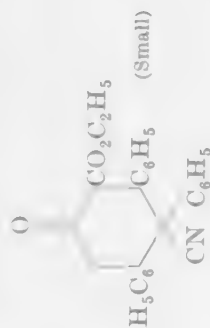
Note: References 491-1045 are on pp. 545-555.

* This product was isolated after hydrolysis.

TABLE XVI—*Continued*
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Cinnamate and</i>		$A = C_6H_5CHCH_2CO_2C_2H_5$	
Diethyl malonate†	$NaOC_2H_5$	$A CH(CO_2C_2H_5)_2$ (quant.)	2, 24, 878, 947
Diethyl methylmalonate	$NaOC_2H_5$ (catalyt. amt.) $NaOC_2H_5$ (1 equiv.)	$AC(CH_3)(CO_2C_2H_5)_2$ (50) $C_6H_5CHCH(CH_3)CO_2C_2H_5$ $CH(CO_2C_2H_5)_2$ (Mixture of 2 isomers, 40)	2, 24, 878, 947 50 50
Ethyl isobutyrate	$NaOC_2H_5$ $(C_6H_5)_3CNa$	$(CH_3)_2C(A)CO_2C_2H_5$ (50)	468
Diethyl succinate	$NaOC_2H_5$	$(CH_3)_2C(A)CO_2C_2H_5$ (20)	468
Diethyl phenylacetate	$NaOC_2H_5$ $(C_6H_5)_3CNa$	2-Phenylbutane-1,3,4-tricarboxylic acid (24)* $C_6H_5CH(A)CO_2C_2H_5$ (quant.)	948 81, 82
Ethyl acetoacetate‡	$(C_6H_5)_3CNa$	$C_6H_5CH(A)CO_2C_2H_5$ (10)	468
Ethyl cyanacetate	$(C_6H_5)_3CNa$ $NaOC_2H_5$	$CH_3COCH(A)CO_2C_2H_5$ (60) $NCCH(A)CO_2C_2H_5$ (two isomers, 85)	468 290, 79, 80, 949
Cyanoacetamide	Na enolate	3-Cyano-2,6-dioxo-4-phenylpiperidine	843
Ethyl α -cyanobutyrate	$NaOC_2H_5$	$NCC(C_2H_5)(A)CO_2C_2H_5$	80
Ethyl α -cyanosuccinate	$NaOC_2H_5$	$NCC(C_3H_7)(A)CO_2C_2H_5$	80
Ethyl α -cyanohydrocinnamate	$NaOC_2H_5$	$NCC(CH_2C_6H_5)(A)CO_2C_2H_5$	80

$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN}$ (Two isomers: 27 total; 50 total; and 27, 83, 32 + 12 or 44 total)
 $\text{C}_6\text{H}_5\text{CH}(\text{A})\text{CN}$ (80); $\text{C}_6\text{H}_5\text{CH}(\text{CN})\text{CH}(\text{C}_6\text{H}_5)\text{CH}_2\text{CO}_2\text{H}$ (Small);



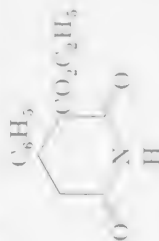
Dry NaOC_2H_5

83, 952,
951

Note: References 491–1095 are on pp. 545–555.

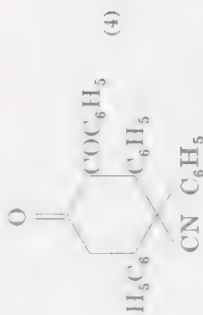

* This product was isolated after hydrolysis.

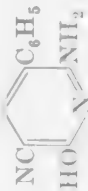
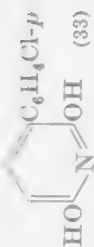

According to ref. 80, amides of cinnamic acid and cinnamionitrile react analogously. Hydrolysis of the primary condensation product affords, with partial decarboxylation, β -phenylglutaric acid. The primary product from cinnamamide is



Ethyl acetate was used; it was transformed into ethyl acetoacetate before the reaction with ethyl cinnamate.

TABLE XVI—Continued

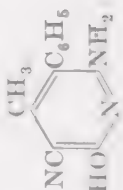
MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS			
Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Cinnamate (Cont.) and</i>			
Benzyl cyanide (Cont.)	NaOCH ₃ Dry NaOH	$A = C_6H_5CHCH_2CO_2C_2H_5$ $C_6H_5CH(CN)CH(C_6H_5)CH_2CO_2CH_3$ $C_6H_5CH(4-CN)(33); C_6H_5CH(CN)CH(C_6H_5)CH_2CO_2H$ (35); $C_6H_5CH(4)CONH_2$ (12)	83 950
Benzoyle- α,β -diphenyl- butyromethide	NaOC ₂ H ₅	 (4)	952
Pinacolone Acetylacetone	NaNH ₂ NaNH ₂	$ACH_2COC(CH_3)_3$ (64) $ACH_2COC_6H_5$ (19) or $C_6H_5COCCH_2CH(C_6H_5)CH_2CO_2H$ (37-66)	327 327, 953
Nitrobenzene Ethyl nitroacetate	$[C_6H_5CH_2N(CH_3)_3]OC_4H_9$ $[C_6H_5CH_2N(CH_3)_3]OH$	ACH_2NO_2 (76) $ACH(NO_2)CO_2C_2H_5$ (66)	40 154
2-Quinoline	—	 (10*)	374
Triethyl phosphonoacetate	NaOC ₂ H ₅ ; K	$(C_2H_5O)_2P(O)CH(A)(CO_2C_2H_5)$ (24, 50)	124, 817
<i>Ethyl 4-Nitrocinnamate and</i> <i>Cyanomethanide</i>	Na enolate	3-(Cyano-2,6-dioxo-4-(<i>p</i> -nitrophenyl)piperidine	843

<i>Ethyl β-Hydroxycinnamate and</i> $\text{CH}_3\text{C}(\text{CN})=\text{CHCO}_2\text{C}_2\text{H}_5$ None	
<i>Ethyl Acrylate, Phenylacrylonitrile and</i> Phenylacrylate-1,1,2,2- NaOC_2H_5 Carboxylate	
<i>Ethyl β-Methoxy-α-phenylacrylate and</i> Cyanacetamide NaOC_2H_5	
<i>β-Methoxy-α-phenylacrylonitrile and</i> Cyanacetamide NaOC_2H_5	
<i>Ethyl β-Ethoxy-α-(p-chlorophenyl)acrylate and</i> Cyanacetamide NaOC_2H_5	
<i>Ethyl β-Isobutoxy-α-phenylacrylate and</i> Cyanacetamide NaOC_2H_5	
<i>β-Isobutoxy-α-phenylacrylonitrile and</i> Cyanacetamide NaOC_2H_5	
6-Hydroxy-2-methyl-4-phenylpyridine-3-carboxylic acid (25)*	954
$\text{C}_6\text{H}_5\text{O}_2\text{CCH}(\text{C}_6\text{H}_5)\text{CH}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2\text{CH}_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$	56
2,6-Dihydroxy-3-phenylpyridine (28)	955
 (78)	955
or	
 (33)	955
2,6-Dihydroxy-3-phenylpyridine (31)	955
 (81)	955

Note: References 491–1045 are on pp. 545–555.

* This product was isolated after hydrolysis.

TABLE XVI—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS			References
Reactants	Catalyst	Product (Yield, %)	
<i>Ethyl p-Methylcinnamate and Ethyl α-cyanopropionate</i>	NaOC_2H_5	$\text{CH}_3\text{C}(\text{CN})(\text{CO}_2\text{H}_5)\text{CH}(\text{C}_6\text{H}_4\text{CH}_3\text{-}p)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$	80
<i>Ethyl α-Methylcinnamate and Ethyl cyanoacetate</i>	NaOC_2H_5	$\text{NCCCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{C}_6\text{H}_5)\text{CH}(\text{CH}_3)\text{CO}_2\text{C}_2\text{H}_5$ (Two isomers, 58)	50, 80
<i>Ethyl Hydroxymethylenephénylacetate and Malonic acid</i>	None	α -Phenylglutaconic acid (75)*	366
<i>Cyanoacetic acid</i>	None	Ethyl 4-cyano-2-phenyl-2-butenolate (47)	366
<i>Ethyl β-Benzylacrylate and Diethyl malonate</i>	Na enolate	$A = \text{C}_6\text{H}_5\text{CH}_2\text{CHCH}_2\text{CO}_2\text{C}_2\text{H}_5$	956
<i>Diethyl methylmalonates</i>	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (51)	77
<i>Ethyl cyanoacetate</i>	NaOC_2H_5	$\text{AC}(\text{CH}_3)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (42)	77
		$\text{ACH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (67)	
<i>β-Isobutyroxy-α-phenylcrotononitrile and Cyanoacetamide</i>	NaOC_2H_5	 (33)	955
<i>Dimethyl Benzylidenemalonate and Diethyl malonate</i>	NaOC_2H_5	$A = \text{C}_6\text{H}_5\text{CHCH}(\text{CO}_2\text{CH}_3)_2$	957
<i>Diethyl benzoin</i>	NaOC_2H_5	$(\text{CH}_3)_2\text{C}(A)\text{CHO}$ (80)	163
		$\text{C}_6\text{H}_5\text{COCCH}(\text{C}_6\text{H}_5)_2$ (44)	

Anthrone	NaOCH ₃		163
Nitromethane	NaOCH ₃	ACH_2NO_2 (95)	329
<i>Dimethyl m-Nitrobenzylidenemalonate and</i>			
Anthrone	Piperidine		958
Phenyltrimethane	NaOCH ₃	$\text{C}_6\text{H}_5\text{CH}(\text{NO}_2)\text{CH}(\text{C}_6\text{H}_4\text{NO}_2\text{-}m)\text{CH}(\text{CO}_2\text{CH}_3)_2$ (78)	959
<i>Dimethyl o-Chlorobenzylidenemalonate and</i>			
Anthrone	Piperidine		960

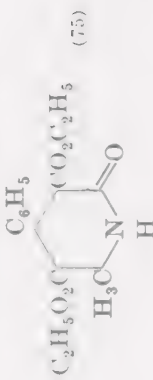
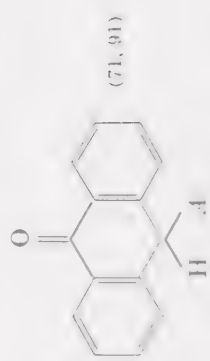
Note: References 491-1045 are on pp. 545-555.

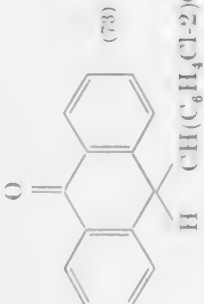
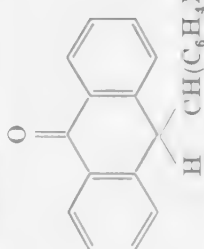
* This product was isolated after hydrolysis.

† Instead of ethyl β-benzylacrylate, ethyl styrylacrylate was employed.

TABLE XVI—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Diethyl benzylidenemalonate and</i>		$A - C_6H_5CHCH(CO_2C_2H_5)_2$	
Diethyl malonate	Na enolate	$ACH(CO_2C_2H_5)_2$ (quant.)	901
Ethyl acetate	$NaOC_2H_5$	$(CH_3COCH(A)CO_2C_2H_5)$ (81)	961
$CH_3CO-NHCH_2CO_2C_2H_5$	None	 (75)	962, 580, 963
Ethyl isobutyrylacetate	$NaOC_2H_5$	$(CH_3)_2CHCOCH(A)CO_2C_2H_5$ (65)	964
Anthrone	Piperidine; $(C_2H_5)_2NH$	 (71, 91)	46, 960
Deoxybenzoin	$NaOC_2H_5$	$C_6H_5COCH(A)C_6H_5$	416
Phenylhydromethane	$(C_2H_5)_2NH$; $NaOC_2H_5$	$C_6H_5CH(A)NO_2$ (86, 52)	29, 965
Ethyl nitroacetate	$(C_2H_5)_2NH$	$ACH(NO_2)CO_2C_2H_5$ (99)	29

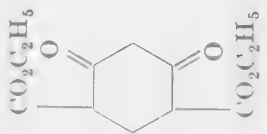
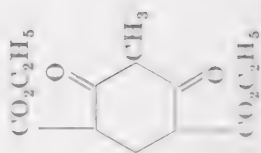
Substituted Diethyl Benzylidenemalonates				
Substituent(s) in $\text{C}_6\text{H}_4\text{CH}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$	Addend	Catalyst	Product (Yield, %)	References
2-Chloro	Anthrone	Piperidine	 (73)	960
3-Nitro	Diethyl malonate	Na enolate	$(\text{C}_2\text{H}_5\text{O}_2\text{C})_2\text{CHCH}(\text{C}_6\text{H}_4\text{NO}_2-3)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	901
	Anthrone	Piperidine		958
4-Nitro	Nitromethane	NaOC_2H_5	$\text{O}_2\text{NCH}_2\text{CH}(\text{C}_6\text{H}_4\text{NO}_2-3)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	966
	Diethyl malonate	Na enolate	$(\text{C}_2\text{H}_5\text{O}_2\text{C})_2\text{CHCH}(\text{C}_6\text{H}_4\text{NO}_2-4)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	901
	Nitromethane	NaOC_2H_5	$\text{O}_2\text{NCH}_2\text{CH}(\text{C}_6\text{H}_4\text{NO}_2-4)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	966
4-Methoxy	Deoxybenzoin	NaOC_2H_5	$\text{C}_6\text{H}_5\text{C}(\text{OCH}(\text{C}_6\text{H}_5)(\text{C}_6\text{H}_5)\text{OC}(\text{H}_3-4)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	416
4-Dimethylamino	Deoxybenzoin	NaOC_2H_5	$\text{C}_6\text{H}_5\text{C}(\text{OCH}(\text{C}_6\text{H}_5)(\text{C}_6\text{H}_5)\text{N}(\text{CH}_3)_2-4)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	416
3,4-Methylenedioxy	Deoxybenzoin	NaOC_2H_5	$\text{C}_6\text{H}_5\text{C}(\text{OCH}(\text{C}_6\text{H}_5)(\text{C}_6\text{H}_3(\text{O}_2\text{CH}_2)_2-3,4)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	416

Note: References 491–1045 are on pp. 545–555.

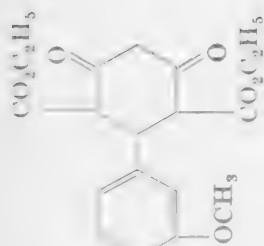
TABLE XVI—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS

Substituted Diethyl Benzylidenemalonates—Continued

Substituent(s) in $C_6H_5CH=C(CO_2C_2H_5)_2$	Addend	Catalyst	Product (Yield, %)	References
4-Acetoxy	Ethyl acetoacetate	$NaOC_2H_5$		967
Ethyl propionyl- acetate	$NaOC_2H_5$	$p-CH_3CO_2C_6H_4$		426

968



3-Methoxy-4-acetoxy

Ethyl acetoacetate

NaOC₂H₅

Reactants

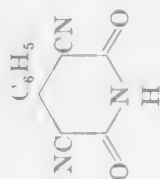
Catalyst

Product (Yield, %)

References

Ethyl Benzylidenecyanoacetate and

Ethyl cyanoacetate

(C₂H₅)₂NH

(Diethylammonium salt, 60)

969

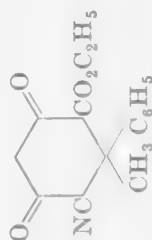
C₆H₅CN + NH(CH₂)₂CN(C₂H₅)₂NH

3,5-Dicyano-4,6-diphenyl-2-piperidone (5)

331

Ethyl (α-Phenylethylidene)cyanoacetate and

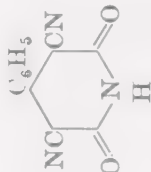
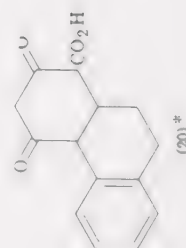
Ethyl acetoacetate



NaOC₂H₅

415

Note: References 491-1045 are on pp. 545-555.

TABLE XVI—Continued

MICHAEL CONDENSATIONS WITH AROMATIC α,β -ETHYLENIC ESTERS		References
Reactants	Product (Yield, %)	
<i>Benzylidenecyanoacetamide and Cyanoacetamide</i>	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}(\text{CN})\text{CONH}_2$ or $\text{C}_6\text{H}_5\text{CH}=\text{C}(\text{CN})\text{CONH}_2$	896
KOH		
<i>Ethyl Cinnamylideneacetate and Diethyl malonate</i>	β -Styrylglutaric acid (38)*	194, 195
NaOC_2H_5		
<i>Ethyl 3,4-Dihydrocouphthoate and Ethyl acetooacetate</i>		970
—	—	
<i>Ethyl 4-Phenyl-2-pentenoate and Ethyl cyanoacetate</i>	$\text{C}_6\text{H}_5\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (56)	77
—	—	

<i>Diethyl 3-Pyridylmethylmalonate and</i> Phenylnitromethane	$(\text{C}_2\text{H}_5)_2\text{NH}$		$\text{CH}[\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2]\text{CH}(\text{C}_6\text{H}_5)\text{NO}_2$	29
<i>Ethyl nitroacetate</i>	$(\text{C}_2\text{H}_5)_2\text{NH}$		$\text{CH}[\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2]\text{CH}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5$	29
<i>Dimethyl Cinnamylidenemalonate and</i> Dimethyl malonate Nitromethane	NaOCH_3 NaOCH_3		$\text{C}_6\text{H}_5\text{CH}[\text{CH}(\text{CO}_2\text{CH}_3)_2]\text{CH}_2\text{CH}[\text{CH}(\text{CO}_2\text{CH}_3)_2]_2$ $\text{C}_6\text{H}_5\text{CH}=\text{CHCH}(\text{CH}_2\text{NO}_2)\text{CH}(\text{CO}_2\text{CH}_3)_2$ (87)	56, 971 329
<i>Diethyl Benzylidenesuccinate and</i> Diethyl malonate	KOC_2H_5		2-Phenylbutane-1,1,3,4-tetracarboxylic acid,* 2-phenylbutane-1,3,4-tricarboxylic acid*	948
<i>Ethyl α-Cyano-γ,γ-diphenylcrotonate and</i> Ethyl cyanoacetate ^a	$(\text{C}_2\text{H}_5)_2\text{NH}$		β-Benzhydrylglutaric acid* (12-21)	972

Note: References 491-1045 are on pp. 545-555.

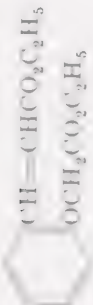
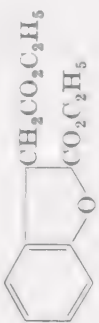
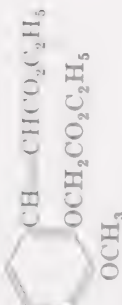
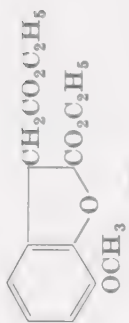



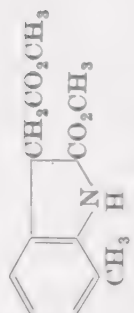
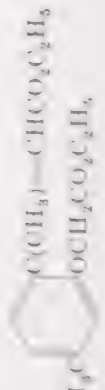
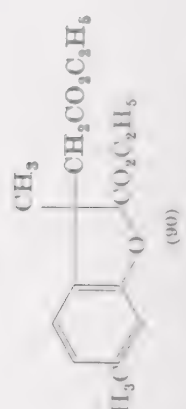
* This product was isolated after hydrolysis.






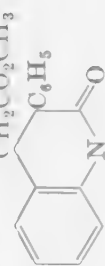
This is the formula of the expected condensation product; in fact, a pentamethyl ester was isolated. This same product is obtained in 97% yield when cinnamaldehyde and dimethyl malonate are condensed in the presence of sodium methoxide.

^a The unsaturated ester was formed *in situ* from diphenylacetaldehyde and ethyl cyanoacetate.

TABLE XVI A

INTRAMOLECULAR MICHAEL CONDENSATIONS OF AROMATIC α,β -ETHYLENIC ESTERS

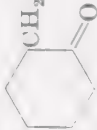

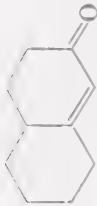
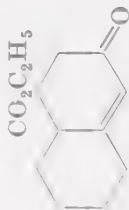
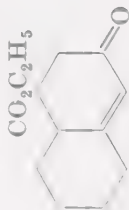
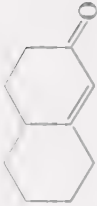
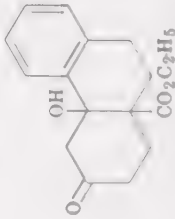
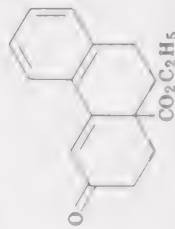
Reactant	Catalyst	Product (Yield, %)	References
	NaOC ₂ H ₅	 (77)	974, 973
	NaOC ₂ H ₅	 (65)	973
	NaOCH ₃	 (75)	332
	NaOCH ₃	 (60)	332
	NaOC ₂ H ₅	 (90)	973, 974

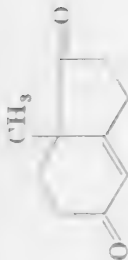
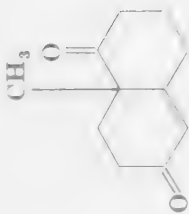
	NaOC_2H_5	974
	NaOC_2H_5	974, 973
	NaOCH_3	332
	NaOCH_3	332
	NaOC_2H_5	974
	NaOCH_3	332

Note: References 491-1045 are on pp. 545-555.

TABLE XVII

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Sodium Methyleneacetoacetate* and</i>			
2-Carboxycyclohexanone	NaOH	  and 	528
2-Carbethoxycyclohexanone	NaOH	  and 	528
2-Methylcyclopentane-1,3-dione	NaOH, piperidine	8-Hydroxy-9-methylhydriindane-3,6-dione	528
2-Methylcyclohexane-1,3-dione	NaOH	2-(β -Acetyloethyl)-2-methylcyclohexane-1,3-dione	528
<i>Ethyl Methyleneacetoacetate† and</i>			
Ethyl acetoacetate	NaOH, <i>sec</i> -amine	4-Carbethoxy-3-methyl-2-cyclohexen-1-one	528
2-Carbethoxycyclohexanone	NaOH	10-Carbethoxy-2-oxo-2,3,4,5,6,7,8,10-octahydronaphthalene	528
2-Carbethoxy-1-tetralone	NaOH	 	528
2-Formyl-1-cyclohexanone	NaOH	2-(β -Acetyl- β -carboxyethyl)-2-formylcyclohexanone (37)	528

<i>Sodium Methyleneacetonedicarboxylate† and</i>			
2 Methylcyclopentane-1,5-dione	NaOH		528
			
2 Methylcyclohexane-1,3-dione	NaOH		528
			
<i>Ethyl α-(Aminomethylene)acetoacetate and</i>			
Ethyl acetoacetate	None	Diethyl 2,6-dimethylpyridine-3,5-dicarboxylate (30)	120
Acetone	None	Ethyl 2,5,6-trimethylpyridine-3-carboxylate (8)	120
Cyclohexanone	None	Ethyl 2-methyl-5,6,7,8-tetrahydroquinoline-3-carboxylate (20-30)	120
<i>Ethyl β-Acetylacrylate and</i>			
Diethyl malonate	NaOC ₂ H ₅	CH ₃ COCH ₂ CH(CO ₂ C ₂ H ₅)(CH(CO ₂ C ₂ H ₅) ₂)	975
<i>Ethyl β-Acetyl-α-hydroxyacrylate (Acetylpyruvate) and</i>			
Cyanoacetamide	NH ₃ ; (C ₂ H ₅) ₂ NH	4-Carbethoxy-3-cyano-6-methyl-2-pyridone	371
	Piperidine	4-Carbethoxy-3-cyano-6-methyl-2-pyridone (15)	976
	NaOCH ₃	4-Carbethoxy-3-cyano-6-methyl-2-pyridone (65)	976
	K ₂ CO ₃	4-Carbethoxy-3-cyano-6-methyl-2-pyridone (82)	976, 977
CH ₃ C(=NH)(CH ₂ CO ₂ C ₂ H ₅)	None	Diethyl 2,6-dimethylpyridine-3,4-dicarboxylate (90)	978, 979

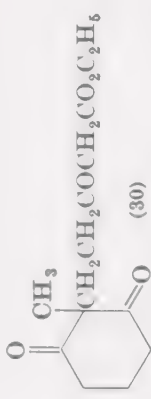
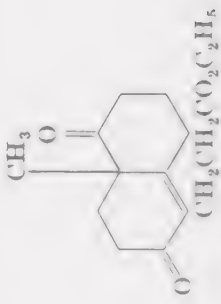
Note: References 491-1045 are on pp. 545-555.

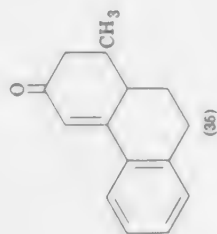
* A mixture of sodium acetoacetate and formaldehyde was employed.

† A mixture of ethyl acetoacetate and formaldehyde was employed.

‡ A mixture of sodium acetonedicarboxylate and formaldehyde was employed.

TABLE XVII—Continued

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS			References
Reactants	Catalyst	Product (Yield, %)	
<i>Ethyl β-Acetyl-α-ethoxyacrylate and</i> Cyanacetamide	K_2CO_3	2-Carbethoxy-5-cyano-4-methyl-6-pyridone (73)	99
<i>Ethyl 3-Oxo-4-pentenoate and</i>			
2-Methylcyclohexane-1,3-dione	$NaOCH_3$	 (30)	538
<i>Ethyl α-Acetyl-β-hydroxycrotonate (Diacetylacetal) and</i> Cyanacetamide	Pyridine	3-Cyano-4-methyl-6-hydroxy-2-pyridone§	398
<i>Methyl 5-Oxo-6-heptenoate and</i>			
2-Methylcyclohexane-1,3-dione	$NaOCH_3$	 (58)	538
<i>Ethyl β-Propionyl-α-hydroxyacrylate (Propionylpyruvate) and</i> Cyanacetamide	Piperidine	Ethyl 3-cyano-6-ethyl-2-hydroxypyridine-4-carboxylate (58)	980

981, 982,
983Diethyl α,α' -diacetyl- β -methylglutarate (93)

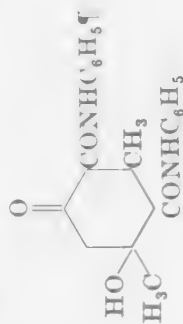
206

 NaNH_2

1-Tetralone

Ethylideneneacetacetanilide and

Acetoacetanilide

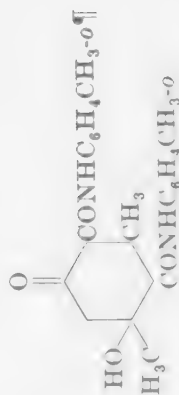
Pyridine
None984
984

Pyridine

984

Ethylideneneacetacet-o-toluide and

Acetoacet-o-toluide



Pyridine

984

Note: References 491–1045 are on pp. 545–555.


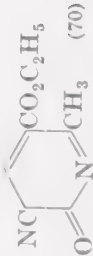
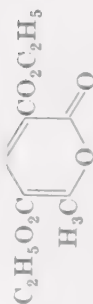
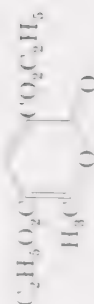
§ Ethyl acetate is eliminated in this reaction.


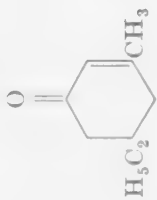
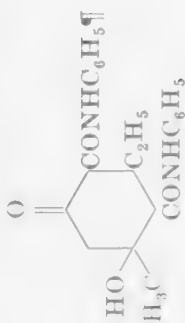
¶ The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

* This product is formed when the reaction is carried out in boiling pyridine.

TABLE XVII—Continued

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethylideneacetacet-p-toluide and</i> Acetoacet-p-toluide	None	$\text{CH}_3\text{CH}[\text{CH}(\text{CO}_2\text{CH}_3)(\text{CONHC}_6\text{H}_4(\text{CH}_3-p))]_2$	984
<i>Ethyl α-Methoxymethyleneacetacetate and</i> Cyanacetamide	Pyridine NaOC_2H_5		984
<i>Ethyl α-Ethoxymethyleneacetacetate and</i> Diethyl malonate	NaOC_2H_5		330
<i>Ethyl β-n-Butyryl-α-hydroxyacrylate (n-Butyrylpyruvate) and</i> Cyanacetamide	Pyridine		310
<i>Ethyl β-n-Butyryl-α-hydroxyacrylate (n-Butyrylpyruvate) and</i> Cyanacetamide	Pyridine		310
<i>Ethyl 3-cyano-2-hydroxy-6-propylpyridine-4-carboxylate</i> (51)			985

Ethyl β -Isobutyryl- α -hydroxyacrylate (Isobutyrylpyruvate) and Isobutyroacetamide	K ⁺ O ⁻	Ethyl 3-cyano-2-hydroxy-6-isopropylpyridine-4-carboxy- late (70)	977
4-Carbomethoxy-3-methyl-2-cyclohexen-1-one and Diethyl malonate	Na enolate		986
Ethyl α -Propylideneacetate and Ethyl acetate	NaOC ₂ H ₅ ; (C ₂ H ₅) ₂ NH	Diethyl α , α -diacetyl- β -ethylglutarate	982, 983, 986a
α -Propylideneacetanilide [†] and Acetanilide	Piperidine		982
	None	C ₂ H ₅ CH(CH(COCH ₃)(CONHC ₆ H ₅)) ₂	984
	Pyridine		984

Note: References 491–1045 are on pp. 545–555.

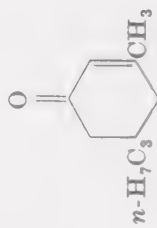
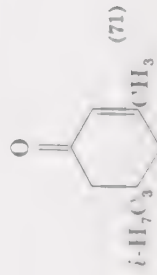
[†] The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

[‡] This product is formed when the reaction is carried out in *boiling* pyridine.

** This is the structure assumed by the authors.

TABLE XVII—Continued

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl α-Isopropylideneacetoacetate</i> and <i>Ethyl acetoacetate</i>	NaOC_2H_5 ; $\text{KOC}(\text{CH}_3)_3$	4-Carboxy-3,5,5-trimethyl-2-cyclohexen-1-one (80–94, 76)	988, 989, 987
<i>Ethyl β-Isobutyryl-α-hydroxyacrylate</i> (<i>Isobutyrylpyruvate</i>) and (γ -acetoacetamide)	K_2CO_3	Ethyl 3-cyano-2-hydroxy-6-isobutylpyridine-4-carboxy- late (65)	977
<i>Ethyl β-Pivaloyl-α-hydroxyacrylate</i> (<i>Pivaloylpyruvate</i>) and (γ -acetoacetamide)	K_2CO_3	Ethyl 3-cyano-2-hydroxy-6- <i>t</i> -butylpyridine-4-carboxy- late (70)	977
<i>Ethyl α-n-Butylideneacetoacetate</i> and <i>Ethyl acetoacetate</i>	Piperidine		981
<i>Ethyl α-Isobutylideneacetoacetate</i> and <i>Ethyl acetoacetate</i>	NaOC_2H_5 ; $(\text{C}_2\text{H}_5)_2\text{NH}$	Diethyl α,α' -diacetyl- β -isopropylglutarate	981, 990
<i>Ethyl α-Isobutylideneacetoacetate</i> and <i>Ethyl acetoacetate</i>	Piperidine		981

Ethyl 6-Carbethoxy-6-methyl-2-cyclohexen-1-one and

Diethyl malonate

 NaOC_2H_5 

991

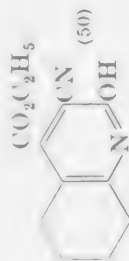
Ethyl (2-Ketocyclohexyl)glyoxalate Enol and $\text{CH}_3\text{C}(\text{O})\text{—NHCH}_2\text{CO}_2\text{C}_2\text{H}_5$

None

Diethyl 2-methyl-9-hydroxy-5,6,7,8,9,10-hexahydroquinoline-3,4-dicarboxylate (36)

652

Cyanacetamide

Piperidine;
 NaOC_2H_5 

977, 592

Diethyl acetone-1,3-dicarboxylate

Na enolate

Triethyl 6-hydroxytetralin-5,7,8-tricarboxylate (72)

427

Methyl β-Benzoylacrylate and

Nitromethane

 NaOCH_3 $\text{C}_6\text{H}_5\text{COCH}_2\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{NO}_2$ (92)

329

Ethyl α-Hydroxy-β-benzoylacrylate and

Cyanacetamide

 $(\text{C}_2\text{H}_5)_2\text{NH}$

4-Carbethoxy-3-cyano-6-phenyl-2-pyridone

594

Ethyl α-Isopentylideneacetoacetate and

Ethyl acetoacetate

 $(\text{C}_2\text{H}_5)_2\text{NH}$;
piperidine

Diethyl α,α'-diacetyl-β-isobutylglutarate

990

Note: References 491–1045 are on pp. 545–555.The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

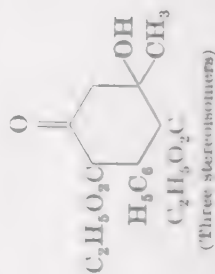
TABLE XVII—Continued

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS			References
Reactants	Catalyst	Product (Yield, %)	
<i>Ethyl (2-Keto-3-methylcyclohexyl)glyoxalate and</i> $(\text{CH}_3\text{C}(\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$	None	Diethyl 2,8-dimethyl-9-hydroxy-5,6,7,8,9,10-hexahydro-quinoline-3,4-dicarboxylate	652
<i>Ethyl (2-Keto-4-methylcyclohexyl)glyoxalate and</i> $(\text{CH}_3\text{C}(\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$	None	Diethyl 2,7-dimethyl-9-hydroxy-5,6,7,8,9,10-hexahydro-quinoline-3,4-dicarboxylate	652
<i>Ethyl (2-Keto-5-methylcyclohexyl)glyoxalate and</i> $(\text{CH}_3\text{C}(\text{NH})\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5)$	None	Diethyl 2,6-dimethyl-9-hydroxy-5,6,7,8,9,10-hexahydro-quinoline-3,4-dicarboxylate	652
<i>Ethyl Methylenebenzoylacetate and</i> Ethyl benzoylacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{CH}_2[\text{CH}(\text{COC}_6\text{H}_5)(\text{O}_2\text{C}_2\text{H}_5)_2]$	992
<i>Ethyl β-Benzoyl-α-hydroxyacrylate (Benzoylpyruvate) and</i> Cyanacetamide	Piperidine	Ethyl 3-cyano-2-hydroxy-6-phenylpyridine-4-carboxylate (30)	977
<i>Ethyl γ-Benzylideneacetoacetate and</i> Decyl benzoin	NaOC_2H_5	3,4,5-Triphenyl-2-cyclohexen-1-one	993

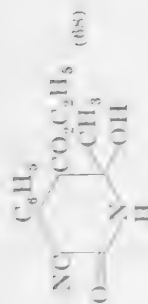
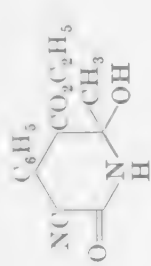
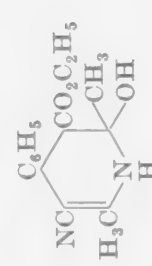
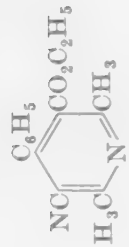
Ethyl α -Benzylideneacetoacetate and

Ethyl acetoacetate ||

Piperidine



982

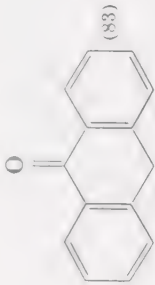
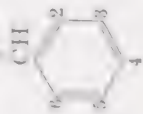
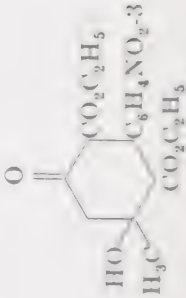
Ethyl cyanacetate	$(C_2H_5)_2NH$		969
	Aq. $(C_2H_5)_2NH$	$C_2H_5O_2CCH(COCH_3)CH(C_6H_5)CH(CN)CONH_2; $	969
	$(C_2H_5)_2NH$		
$(CH_3)_3C-NH-CH_2CN$	$(C_2H_5)_2NH$		440
		or 	
$C_6H_5C(=NH)CH_2CN$	$NaOCH_3$	Ethyl 5-cyano-4,6-diphenyl-2-methylpyridine-3-carboxylate††	331
$p-CH_3C_6H_4C(=NH)CH_2CN$	$NaOCH_3$	Ethyl 5-cyano-2-methyl-4-phenyl-6- <i>p</i> -tolylpyridine-3-carboxylate	331
$p-CH_3OC_6H_4C(=NH)CH_2CN$	$NaOCH_3$	Ethyl 5-cyano-6- <i>p</i> -methoxyphenyl-2-methyl-4-phenylpyridine-3-carboxylate	331
Phenylacetaldehyde	$NaOC_2H_5$	$C_6H_5CH[CH(C_6H_5)CHO]CH(COCH_3)CO_2C_2H_5$ (36)	163

Note: References 491-1045 are on pp. 545-555.

† The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

†† By self-condensation, part of the $C_6H_5C(=NH)CH_2CN$ is converted into 3,5-dicyano-2,4,6-triphenyldihydropyridine.

TABLE XVII—Continued
MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl α-benzylidenemalonate (Cont.) and</i>			
Anthrone	NaOC_2H_5	 (83)	163
Phenylnitromethane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{C}_6\text{H}_5\text{CHCH}(\text{COCH}_3)\text{CO}_2\text{C}_2\text{H}_5$ 3-(Carbethoxy-5-nitro-4,5-diphenyl-2-pentanone (78))	29
<i>Substituted Ethyl α-Benzylidenemalonates</i>			
Substituent(s) in $\text{CH}_3\text{COCOCOC}_2\text{H}_5$	Addend	Catalyst	Product (Yield, %)
 4			
3-Nitro	Ethyl acetate	Piperidine	 982, 994


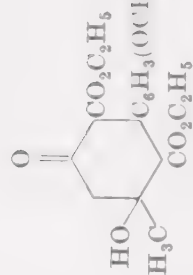
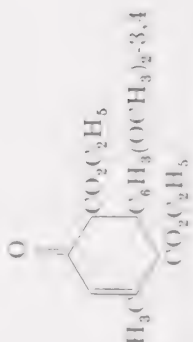
Decylbenzoin	NaOC_2H_5	$3\text{-O}_2\text{NC}_6\text{H}_4\text{CH}(\text{COCH}_3)\text{CO}_2\text{C}_2\text{H}_5$ $\text{C}_8\text{H}_9\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)$	416
4-Nitro	Ethyl acetoacetate	Piperidine	982, 994
			982; cf. 995
2-Methoxy	Ethyl acetoacetate	NaOC_2H_5	996 996
3-Cyano 4-Cyano	Ethyl acetoacetate Ethyl acetoacetate	Pyridine Pyridine	536
3,4-Methylenedioxy	Ethyl acetoacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	

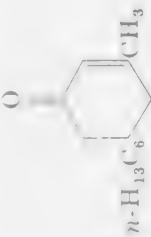
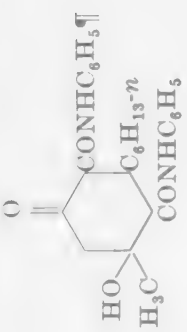
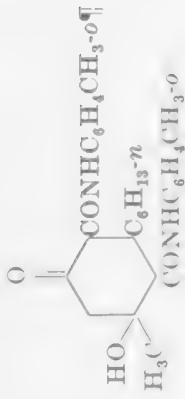
Note: References 491–1045 are on pp. 545–555.

The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

TABLE XVII—Continued

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERSSubstituted Ethyl α -Benzylidenacetates—Continued

Substituent(s) in $\text{CH}_2=\text{C}(\text{OCOC}_2\text{H}_5)_2$	Addend	Catalyst	Product (Yield, %)	References
	Ethyl acetoacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 (14)	536
			 (Mixtures of stereoisomers, 34)	

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl α-n-Heptylideneacetate and Ethyl acetoacetate</i>	NaOC_2H_5 ; $(\text{C}_2\text{H}_5)_2\text{NH}$	Diethyl α,α' -diacetyl- β - <i>n</i> -hexylglutarate	980
	Piperidine		981
α - <i>n</i> -Heptylideneacetanilide and Acetoacetanilide	None	$n\text{-C}_6\text{H}_{13}\text{CH}[\text{CH}(\text{COCH}_3)\text{CONHC}_6\text{H}_5]_2$	984
α - <i>n</i> -Heptylideneacet-o-toluide and	Pyridine		984
<i>Acetoacet-o-toluide</i>	Pyridine		984

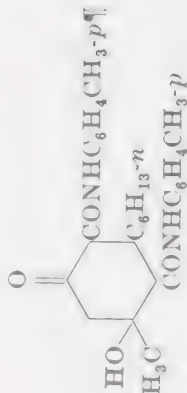
Note: References 491–1045 are on pp. 545–555.

The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

• This product is formed when the reaction is carried out in *boiling* pyridine.

TABLE XVII—Continued

MICHAEL REACTIONS WITH α,β -ETHYLENIC KETO ESTERS

Reactants	Catalyst	Product (Yield, %)	References
α - <i>n</i> -Heptylideneacetacet- <i>p</i> -toluide and			
Acetoacet- <i>p</i> -toluide	Pyridine		984
<i>Ethyl</i> β -Cinnamoyl- α -hydroxyacrylate (Cinnamoylpyruvate) and (H_3C)— $\text{NHCH}_2\text{CO}_2\text{C}_2\text{H}_5$	None	Diethyl 2-methyl-6-styrylpyridine-3,4-dicarboxylate (48)	954
<i>Ethyl</i> α -Benzylideneisobutyrylacetate and Diethyl malonate	NaOC_2H_5	$\text{C}_6\text{H}_5\text{CHCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{COCH}(\text{CH}_3)_2$ $\quad \quad \quad $ $\quad \quad \quad \text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2 \text{ (72)}$	964
<i>Ethyl</i> Citrylideneacetacetate and Ethyl acetacetate	Piperidine	Diethyl citrylidene-bis-acetoacetate (61)	997
<i>Ethyl</i> Benzylidenebenzoylacetate and Phenylnitromethane	$(\text{C}_2\text{H}_5)_2\text{NH}$	Ethyl α -benzoyl- γ -nitro- β,γ -diphenylbutyrate (71)	29

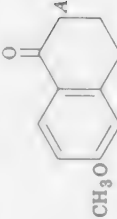
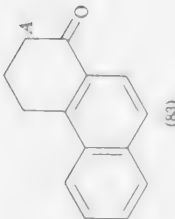
Note: References 491–1045 are on pp. 545–555.

|| The ethylenic compound was formed *in situ* from the corresponding aldehyde and the keto acid derivative.

|| This product is formed when the reaction is carried out in boiling pyridine.

TABLE XVIII

MICHAEL CONDENSATIONS WITH α,β -ACETYLENIC ESTERS

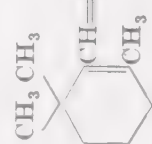
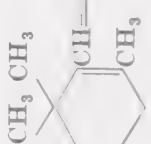
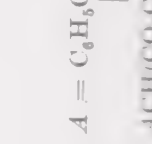
Reactants	Catalyst	Product (Yield, %)	Reference
<i>Methyl Propiolate and</i> 1-Tetralone	NaNH_2 , liq. NH_3	Methyl 1-tetralone-2-acrylate*	998
<i>Ethyl Propiolate and</i> Diethyl methylmalonate Ethyl acetoacetate	Na NaOC_2H_5	$A = -\text{CH}=\text{CHCO}_2\text{C}_2\text{H}_5$ $\text{CH}_3\text{C}(A)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (14) $\text{CH}_3\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$	333 999
6-Methoxy-1-tetralone	NaNH_2 , liq. NH_3		998
1-Keto-1,2,3,4-tetrahydrophenanthrene	NaNH_2 , liq. NH_3	 (83)	998
α -Phenylbutyronitrile	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}-(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{CH}_2\text{C}(\text{C}_6\text{H}_5)(A)\text{CN}$ (35)	1000

Note: References 491-1045 are on pp. 545-555.

* The product was directly reduced to methyl 1-tetralone-2-propionate.

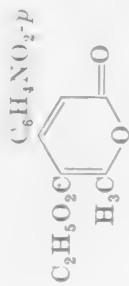
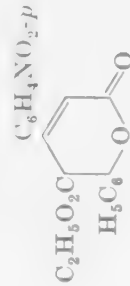
TABLE XVIII—Continued

MICHAEL CONDENSATIONS WITH α,β -ACETYLENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl Propiolate (Cont.) and</i> Diethylamino- α -phenylbutyronitrile	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}-(\text{CH}_3)_3]\text{OH}$	$A = -\text{CH}=\text{CHCO}_2\text{C}_2\text{H}_5$ $(\text{C}_2\text{H}_5)_2\text{NCH}_2\text{CH}_2\text{C}(\text{C}_6\text{H}_5)(A)\text{CN}$ (59)	1000
Diphenylacetoneitrile	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}-(\text{CH}_3)_3]\text{OH}$	$(\text{C}_6\text{H}_5)_2\text{C}(A)\text{CN}$ (92)	1000
<i>Ethyl Tetrolate and</i> Diethyl malonate	NaOC_2H_5	$A = \text{CH}_3\text{C}=\text{CHCO}_2\text{C}_2\text{H}_5$ $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	109, 1001, 1002
CH_3CH_3 	NaOC_2H_5	$\text{CH}=\text{CH}(\text{CH}_3)=\text{CHCOO}(A)(\text{OC}_2\text{H}_5)_2$	1003, 1004
<i>Tetrolonitrile and</i> CH_3CH_3 	NaOC_2H_5	$\text{CH}=\text{CHC}(\text{CH}_3)=\text{CHCOC}(\text{CO}_2\text{C}_2\text{H}_5)_2$ $\text{CH}_3\text{C}=\text{CHCN}$	1003
<i>Ethyl Phenylpropiolate and</i> Diethyl malonate	$\text{Na}; \text{NaOC}_2\text{H}_5$ $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	$A = \text{C}_6\text{H}_5\text{C}=\text{CHCO}_2\text{C}_2\text{H}_5$ $B = \text{C}_6\text{H}_5$ 	23, 26, 578, 1003

β -Phenylglutaconic acid †		1006, 1007, 1008, 333, 25, 26, cf. 334 431
Diethyl methylmalonate	$\text{Na}; \text{NaOC}_2\text{H}_5$	$\text{CH}_3\text{C}(A)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (14)
Diethyl benzylmalonate	NaOC_2H_5	$\text{C}_6\text{H}_5\text{CH}_2\text{C}(A)(\text{CO}_2\text{C}_2\text{H}_5)_2$
Ethyl acetooacetate	NaOC_2H_5	$B, R_1 = \text{CO}_2\text{C}_2\text{H}_5, R_2 = \text{CH}_3$ (14)
Ethyl α -propylacetooacetate	NaOC_2H_5	$(\text{H}_3\text{C}(\text{O}(\text{O}(\text{C}_3\text{H}_7-n)(\text{O})_2\text{C}_2\text{H}_5$
Ethyl oxalacetate	NaOC_2H_5	$B, R_1 = R_2 = \text{CO}_2\text{C}_2\text{H}_5$
Ethyl benzoylacetate	NaOC_2H_5	$B, R_1 = \text{CO}_2\text{C}_2\text{H}_5, R_2 = \text{C}_6\text{H}_5$
Ethyl cyanoacetate	Na	$\text{NCCH}(A)\text{CO}_2\text{C}_2\text{H}_5$
Acetylacetone	NaOC_2H_5	$\text{CH}_3\text{COCH}(A)\text{COCH}_3; B, R_1 = \text{COCH}_3, R_2 = \text{CH}_3$
Benzoylacetone	NaOC_2H_5	$B, R_1 = \text{H}, R_2 = \text{CH}_3$
Deoxybenzoin	NaOC_2H_5	$B, R_1 = \text{COCH}_3, R_2 = \text{C}_6\text{H}_5$
Ethyl fluorene-9-carboxylate	Na enolate	$B, R_1 = R_2 = \text{C}_6\text{H}_5$
		Ethyl β -(9-fluorenyl)cinnamate (28)

Ethyl p-Nitrophenylpropiolate and

Ethyl acetooacetate	NaOC_2H_5		433
Ethyl benzoylacetate	NaOC_2H_5		433

Note: References 491–1045 are on pp. 545–555.

* This product results from hydrolysis and partial decarboxylation.

TABLE XVIII—Continued

MICHAEL CONDENSATIONS WITH α,β -ACETYLENIC ESTERS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl 2,3-Dimethoxyphenylpropionate and Ethyl acetoacetate</i>	NaOC_2H_5	5-Carbethoxy-4-(2',3'-dimethoxyphenyl)-6-methyl- α -pyrone (71)	1011
<i>Acetylacetone</i>	NaOC_2H_5	2,3-(CH_3O) ₂ $\text{C}_6\text{H}_3\text{C}=\text{CHCO}_2\text{C}_2\text{H}_5$ $\text{CH}_3\text{COC}=\text{C}(\text{OH})\text{CH}_3$ (33)†	1011
<i>2,3-Dimethoxyphenylpropionitrile and Acetylacetone</i>	NaOC_2H_5	2,3-(CH_3O) ₂ $\text{C}_6\text{H}_3\text{C}=\text{CHCN}$ $\text{CH}_3\text{COC}=\text{C}(\text{OH})\text{CH}_3$ (43)†	1011
<i>Diethyl Acetylenedicarboxylate and Diethyl malonate</i>	Na	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (30)	333
<i>Diethyl methylmalonate</i>	$\text{Na}; \text{NaOC}_2\text{H}_5$	$\text{CH}_3\text{C}(\text{A})(\text{CO}_2\text{C}_2\text{H}_5)_2$	333
<i>Triethyl ethane-1,1,2-tricarboxylate</i>	NaOC_2H_5	Pentaethyl 1-butene-1,2,3,3,4-pentacarboxylate	325
<i>Tetraethyl ethane-1,1,2,2-tetracarboxylate</i>	NaOC_2H_5	Hexaethyl 1-butene-1,2,3,3,4,4-hexacarboxylate (16)§	325, 489
<i>Ethyl acetoacetate</i>	NaOC_2H_5	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$	433, 1012
<i>Ethyl benzoylacetate</i>	NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$	433, 1012

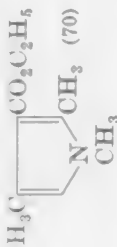
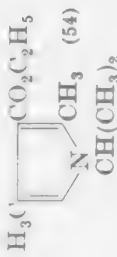
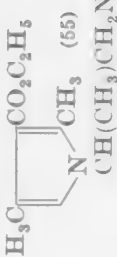
Diethyl Acetylenedicarboxylate and

Note: References 491–1045 are on pp. 545–555.

† The free acid corresponding to this product was actually isolated.

§ Originally (ref. 489), this product was assumed to be a cyclobutane derivative, formed by a second, intramolecular, Michael reaction. The cyclobutane structure has now been disproved (ref. 325).

TABLE XIX

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC NITRO COMPOUNDS		Catalyst	Product (Yield, %)	References
Reactants				
1-Nitro-1-propene and Ethyl acetoacetate		NaOC_2H_5	$\text{O}_2\text{NCH}_2\text{CH}(\text{CH}_3)\text{CH}(\text{COCH}_3)\text{CO}_2\text{C}_2\text{H}_5$ (31)	1013
$\text{CH}_3\text{C}(\text{CH}_3)=\text{NCH}_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$		None	 (70)	1013
$\text{CH}_3\text{C}(\text{CH}_3)=\text{NCH}(\text{CH}_3)_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$		None	 (54)	1013
$\text{CH}_3\text{C}(\text{CH}_3)=\text{NCH}(\text{CH}_3)\text{CH}_2\text{NO}_2$ - $\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$		None	 (55)	1013
2-Nitro-1-propene and 2-Nitropropane Methyl 2-nitropropyl ether Methyl 2-nitropropyl sulfide		NaOC_2H_5 NaOC_2H_5 NaOCH_3	$A = \text{CH}_3\text{CH}(\text{NO}_2)\text{CH}_2-$ $\text{AC}(\text{CH}_3)_2\text{NO}_2$ (20) $\text{AC}(\text{NO}_2)(\text{CH}_3)\text{CH}_2\text{OCH}_3$ (50) $\text{AC}(\text{NO}_2)(\text{CH}_3)\text{CH}_2\text{SCH}_3$ (30)	1014 1014 1014

Note: References 491-1045 are on pp. 545-555.

TABLE XIX—Continued

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC NITRO COMPOUNDS

Reactants	Catalyst	Product (Yield, %)	References
<i>Nitromalonlaldehyde (Hydroxymethylenenitroacetaldehyde) and</i>			
Ethyl acetoacetate	Alkali	5-Nitrosalicylic acid	111
Cyanoacetamide	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	3-Cyano-5-nitro-2-pyridone (93)	111
Levulinic acid	Alkali	2-Hydroxy-5-nitrophenylacetic acid (82)	111
Acetonedicarboxylic acid	Alkali	2-Hydroxy-5-nitrobenzene-1,3-dicarboxylic acid	111
Acetone	Alkali	<i>p</i> -Nitrophenol	339
Methyl ethyl ketone	Alkali	2-Methyl-4-nitrophenol (90)	111
Acetylacetone	Alkali	Methyl 2-hydroxy-5-nitrobenzyl ketone, 2,2'-dihydroxy-5,5'-dinitrobiphenyl	1015, 1016 111, 340, 341
Methyl benzyl ketone	Alkali	2-Hydroxy-5-nitrobiphenyl	111, 340, 341
Dibenzyl ketone	Alkali	2,6-Diphenyl-4-nitrophenol (94)	111, 340, 341
Cyclooctanone	Na enolate	2,6-Pentamethylene-4-nitrophenol* (10)	342, 343
Cyclononanone	Na enolate	2,6-Hexamethylene-4-nitrophenol (62)	342
Cyclodecanone	Na enolate	2,6-Heptamethylene-4-nitrophenol (6)	342
Cycloundecanone	Na enolate	2,6-Octamethylene-4-nitrophenol (2)	343
Cyclododecanone	Na enolate	2,6-Nonamethylene-4-nitrophenol (28)	342
Cyclotridecanone	Na enolate	2,6-Decamethylene-4-nitrophenol (70)	342
Cyclotetradecanone	Na enolate	2,6-Undecamethylene-4-nitrophenol (64)	342
Cyclopentadecanone	Na enolate	2,6-Dodecamethylene-4-nitrophenol (74)	342
Cyclohexadecanone	Na enolate	2,6-Tridecamethylene-4-nitrophenol (63)	342
Cyclodeptadecanone	Na enolate	2,6-Tetradecamethylene-4-nitrophenol (57)	342
Cyclooctadecanone	Na enolate	2,6-Pentadecamethylene-4-nitrophenol (40)	342
Cyclononadecanone	Na enolate	2,6-Hexadecamethylene-4-nitrophenol (43)	343

Cyclohexanone	Na enolate	2,6-Heptadecamethylene-4-nitrophenol (47)	342
Cyclohexenecarboxylic acid	Na enolate	2,6-Octadecamethylene-4-nitrophenol (16)	342
Cyclooctatetraene	Na enolate	2,6-Heptacosamethylene-4-nitrophenol	342
1-Nitro-1-butene and		$A = \text{CH}_3\text{CH}_2\text{CHCH}_2\text{NO}_2$	
Ethyl α -propylacetoacetate	Na	$\text{CH}_3\text{COC}(A)(\text{C}_3\text{H}_7\text{-}n)\text{CO}_2\text{C}_2\text{H}_5$	1017
Ethyl α -cyanobutyrate	NaOC_2H_5	$\text{CH}_3\text{CH}_2\text{C}(\text{CN})(A)(\text{C}_2\text{H}_5)_2$	1018
Benzyl cyanide†	KOC_3H_7	$\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$	1018
Acetylacetone	Na	$\text{CH}_3\text{COCH}(A)\text{COCH}_3$ (30)	1019
2-Nitro-1-butene and		$A = \text{CH}_3\text{CH}_2\text{CH}(\text{NO}_2)\text{CH}_2-$	
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	1020†
Diethyl phenylmalonate	NaOC_2H_5	$\text{C}_6\text{H}_5\text{C}(A)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (13)	1020
Ethyl acetoacetate	Na	$\text{CH}_3\text{COCH}(A)\text{CO}_2\text{C}_2\text{H}_5$ (25)	1017
Methyl cyanoacetate‡	None	$\text{ACH}(\text{CN})(\text{C}_2\text{H}_5)_2$ (23)	1021
Ethyl cyanoacetate	NaOC_2H_5	$\text{ACH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (16 crude)	1018, 1021
1-Nitropropane	NaOH	$\text{CH}_3\text{CH}_2\text{CH}(A)\text{NO}_2$ (18)	1021
2-Nitropropane¶	NaOH	$(\text{CH}_3)_2\text{C}(A)\text{NO}_2$ (55)	1021
Acetylacetone	Na	$(\text{CH}_3)(\text{OCH}(A)(\text{OCH}_3)$	1019

Note: References 491-1045 are on pp. 545-555.

† *Chemical Abstracts* name: 9-Nitrobicyclo[5.3.1]hendeca-1(11),4,9-triene-11-ol.

‡ Instead of 1-nitro-1-butene, β -nitroisopropyl acetate was employed.

§ In this patent, a number of similar products of Michael condensations are mentioned.

¶ 1-Dimethylamino-2-nitrobutane was employed instead of 2-nitro-1-butene.

|| Instead of 2-nitro-1-butene, 1-diethylamino-2-nitrobutane was used. When the corresponding 1-dimethylamino compound was employed, the yield was somewhat higher.

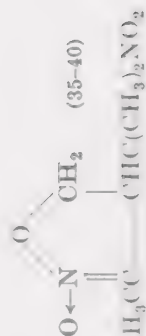
¶ Instead of 2-nitro-1-butene, 1-dimethylamino-2-nitrobutane was employed.

TABLE XIX—Continued

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC NITRO COMPOUNDS

Reactants	Catalyst	Product (Yield, %)	References
2-Nitro-2-butene and		$A = \text{CH}_3\text{CHCH}(\text{NO}_2)\text{CH}_3$	
Benzyl cyanide	NaOCH_3	$(\text{C}_6\text{H}_5\text{CH}(A)\text{CN})$	85
Nitroethane	$[(\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3)\text{OH};$ NaOC_2H_5 ; piperidine	$\text{CH}_3\text{CH}(A)\text{NO}_2$ (28)	1014
2-Nitropropane	NaOC_2H_5	$(\text{CH}_3)_2\text{C}(A)\text{NO}_2$ (47)	1014
2-Methyl-1-nitro-1-propene and		$A = (\text{CH}_3)_2\text{CCH}_2\text{NO}_2$	
Diethyl malonate	NaOC_2H_5	$A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (72)	1020
Ethyl acetoacetate	Na	$\text{CH}_3\text{C}(\text{OCH}(A))\text{CO}_2\text{C}_2\text{H}_5$	1017
Ethyl cyanoacetate	$(\text{C}_2\text{H}_5)_3\text{N}$	$A\text{CH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	1018
Benzyl cyanide	KOC_3H_7 - <i>t</i>	$\text{C}_6\text{H}_5\text{CH}(A)\text{CN}$ (60)	85
<i>p</i> -Bromobenzyl cyanide	$\text{KOC}_5\text{H}_{11}$ - <i>t</i>	<i>p</i> -BrC ₆ H ₄ CH(A)CN (70)	85
Acetone	Na	$A\text{CH}_2\text{COCH}_3$	1022

1-Chloro-3-nitro-2-butene and

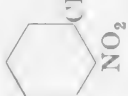
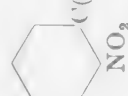


2 Nitropropane

 NaOC_2H_5

1023

 $(\text{CH}_3)_2\text{C}(\text{NO}_2)\text{C}(\text{CH}_3)_2\text{NO}_2$ (10-12) $\text{CH}_3\text{C}(\text{NO}_2)=\text{CHCH}=\text{C}(\text{CH}_3)_2$ (3)

1-Nitro-1-pentene and Diethyl malonate	Na	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_2\text{NO}_2)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (95)	1020
3,3,4,4,5,5,5-Heptafluoro-1-nitro-1-pentene and Nitromethane	NaOC_2H_5 NaOC_2H_5	$A = \text{CF}_3\text{CF}_2\text{CF}_2\text{CHCH}_2\text{NO}_2$ ACH_2NO_2 (68) $\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (54)	803 803
3-Nitro-3-hexene and Diethyl malonate	NaOC_2H_5	$\text{CH}_3\text{CH}_2\text{CH}(\text{NO}_2)\text{CH}(\text{C}_2\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$	1020
<i>Ethyl</i> α -Nitro- γ,γ -trichloroacetate and Ethyl nitroacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{Cl}_3\text{CCH}[\text{CH}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5]_2$ (34)	1024
1-Nitrocyclohexene and <i>p</i> -Bromobenzyl cyanide	$\text{KOC}_5\text{H}_{11}-t$	 (Mixture of isomers, 8)	85
2-Nitropropane	NaOC_2H_5	 (16)	1014

Note: References 491-1045 are on pp. 545-555.

TABLE XIX—Continued

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC NITRO COMPOUNDS			
Reactants	Catalyst	Product (Yield, %)	References
<i>Methyl 2-Nitro-2-pentenoate and</i>			
1,1-Dinitroethane	NaOH, aq. CH_3OH	$\text{AC}(\text{NO}_2)_2\text{CH}_3$ (61)	813
Methyl 2,2-dinitrobutyrate	Na derivative, water	$(\text{NO}_2)_2\text{C}(\text{A})\text{CH}_2\text{CH}_2\text{CO}_2\text{CH}_3$ $\text{A} = \text{CH}_3\text{CH}_2\text{CHCH}(\text{NO}_2)\text{CO}_2\text{CH}_3$	813
<i>1-(α-Furyl)-2-nitroethylene and</i>			
Ethyl nitroacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	Ethyl 3-(α -furyl)-2,4-dinitrobutanoate (95)	622
<i>ω-Nitrostyrene and</i>			
		$\text{A} = \text{C}_6\text{H}_5\text{CHCH}_2\text{NO}_2$	
Dimethyl malonate	Na	$\text{ACH}(\text{CO}_2\text{CH}_3)_2$	329
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (51)	1025
Ethyl acetacetate	Na; $(\text{C}_2\text{H}_5)_3\text{N}$	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (98)	1017, 1025
Ethyl benzoylacetate	Na	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$	1017
Acetylacetone	Na, $(\text{C}_2\text{H}_5)_3\text{N}$	$\text{CH}_3\text{COCH}(\text{A})\text{COCH}_3$ (78)	1019, 1025
Benzoylacetone	$(\text{C}_2\text{H}_5)_3\text{N}$	$\text{C}_6\text{H}_5\text{COCH}(\text{A})\text{COCH}_3$ (86)	1025
Ethyl nitroacetate	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{ACH}(\text{NO}_2)\text{CO}_2\text{C}_2\text{H}_5$ (97)**	154
Phenylnitromethane	$(\text{C}_2\text{H}_5)_2\text{NH}$	$\text{C}_6\text{H}_5\text{CH}(\text{A})\text{NO}_2$ (94)	622
<i>o-Nitrostyrene and</i>			
		$\text{A} = o\text{-O}_2\text{NC}_6\text{H}_4\text{CH}_2\text{CH}_2-$	
Dimethyl malonate	NaOCH_3	$\text{ACH}(\text{CO}_2\text{CH}_3)_2$ (49); $(\text{A})_2\text{C}(\text{CO}_2\text{CH}_3)_2$ (2)	344
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (72)	344
Diethyl ethylmalonate	NaOC_2H_5	$\text{C}_2\text{H}_5\text{CH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (44)	344
Methyl acetacetate	NaOCH_3	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{CH}_3$ (32)	344

Ethyl acetoacetate	NaOC_2H_5	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (42)	344
Ethyl <i>n</i> -butylacetoacetate	NaOC_2H_5	$\text{CH}_3\text{COC}(\text{C}_4\text{H}_9-n)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (61)	344
Methyl cyanoacetate	NaOC_2H_5	$\text{ACH}(\text{CN})\text{CO}_2\text{CH}_3$ (69)	344
Ethyl cyanoacetate	NaOC_2H_5	$\text{ACH}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (78)	344
Cyanoacetamide	NaOC_2H_5	$(\text{A})_2\text{C}(\text{CN})\text{CONH}_2$ (42)	344
<i>p</i> -Nitrostyrene and		$\text{A} = p\text{-O}_2\text{NC}_6\text{H}_4\text{CH}_2\text{CH}_2-$	
Dimethyl malonate	NaOCH_3	$\text{ACH}(\text{CO}_2\text{CH}_3)_2$ (43), $(\text{A})_2\text{C}(\text{CO}_2\text{CH}_3)_2$ (32)	344
Diethyl malonate	NaOC_2H_5	$\text{ACH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (45), $(\text{A})_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (34)	344
Diethyl ethylmalonate	NaOC_2H_5	$\text{AC}(\text{C}_2\text{H}_5)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (56)	344
Methyl acetoacetate	NaOCH_3	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{CH}_3$ (38), $\text{CH}_3\text{COC}(\text{A})_2\text{CO}_2\text{CH}_3$ (24)	344
Ethyl acetoacetate	NaOC_2H_5	$\text{CH}_3\text{COCH}(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (47), $\text{CH}_3\text{COC}(\text{A})_2\text{CO}_2\text{C}_2\text{H}_5$ (19)	344
Ethyl <i>n</i> -butylacetoacetate	NaOC_2H_5	$\text{CH}_3\text{COC}(\text{C}_4\text{H}_9-n)(\text{A})\text{CO}_2\text{C}_2\text{H}_5$ (57)	344
Methyl cyanoacetate	NaOCH_3	$(\text{A})_2\text{C}(\text{CN})\text{CO}_2\text{CH}_3$ (79)	344
Ethyl cyanoacetate	NaOC_2H_5	$(\text{A})_2\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$ (80)	344
Cyanoacetamide	NaOC_2H_5	$(\text{A})_2\text{C}(\text{CN})\text{CONH}_2$ (73)	344
Malononitrile	NaOC_2H_5	$(\text{A})_2\text{C}(\text{CN})_2$ (36)	344
β -Methyl- β -nitrostyrene and			
Dimethyl malonate	Na enolate	Diethyl 3-nitro-2-phenylbutane-1,1-dicarboxylate (79)++††	86

Note: References 491-1045 are on pp. 545-555.




** The product was isolated as the *aci*-diethylanmonium salt.

†† In ether as solvent, only one of the two diastereomerides is formed; in alcohol a mixture of the two is obtained.

‡‡ When the reaction product is worked up with acid, this compound is transformed into 1,1-dicarbethoxy-2-phenylbutan-3-one.

TABLE XIX—Continued

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC NITRO COMPOUNDS

Reactants	Catalyst	Product (Yield, %)	References
<i>Ethyl</i> β -(2-Furyl)- α -nitroacrylate§§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	 (83, 88)**	154, 1024
<i>Ethyl</i> α -Nitro- β -(2-pyridyl)acrylate§§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	 (82, 84)**	154, 1024
<i>Ethyl</i> α -Nitro- β -(3-pyridyl)acrylate§§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	 (55)**	154
<i>Methyl</i> α -Nitrocinnamate§§ and Methyl nitroacetate	CH_3NH_2 ; $(C_2H_5)_2NH$	$C_6H_5CH[CH(NO_2)CO_2CH_3]_2$ (76)	1024
<i>Ethyl</i> α -Nitrocinnamate and Diethyl malonate	$(C_2H_5)_2NH$	$A = C_6H_5CHCH(NO_2)CO_2C_2H_5$ 3,3-Dicarboethoxy-1-nitro-2-phenylbutyric acid diethylamide (82)	1026
<i>Ethyl</i> acetoacetate Benzyl cyanide Ethyl nitroacetate§§	$(C_2H_5)_2NH$ $(C_2H_5)_2NH$ $(C_2H_5)_2NH$	$CH_3COCH(A)CO_2C_2H_5$ (85) $C_6H_5CH(A)CN$ (83) $ACH(NO_2)CO_2C_2H_5$ (80, 84-98, 74)**	1026 1026 154, 1024, 1026
Phenyl nitromethane	$(C_2H_5)_2NH$	$C_6H_5CH(A)NO_2$ (82)	1026

<i>Ethyl</i> α ,2-Dinitrocinnamate §§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	$2-O_2NC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (82, 68)**	154, 1024
<i>Ethyl</i> α ,3-Dinitrocinnamate §§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	$3-O_2NC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (90-95, 66)**	154, 1024
<i>Ethyl</i> α ,4-Dinitrocinnamate and Ethyl acetoacetate	$(C_2H_5)_2NH$	$CH_3COCH(CO_2C_2H_5)CH(C_6H_4NO_2-4)-$ $CH(NO_2)CO_2C_2H_5$ (65)	1026
<i>Ethyl</i> nitroacetate §§	$(C_2H_5)_2NH$	$4-O_2NC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (82, 60, 38)**	154, 1024, 1026
<i>Ethyl</i> 2-Hydroxy- α -nitrocinnamate §§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	$2-HOC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (90, 98)**	154, 1024
<i>Ethyl</i> 4-Hydroxy- α -nitrocinnamate §§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	$4-HOC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (64)**	154
<i>Ethyl</i> 2-Chloro- α -nitrocinnamate §§ and Ethyl nitroacetate	$(C_2H_5)_2NH$	$2-ClC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (97)**	154, 1024
<i>Ethyl</i> 4-Chloro- α -nitrocinnamate and Ethyl acetoacetate	$(C_2H_5)_2NH$	$CH_3COCH(CO_2C_2H_5)CH(C_6H_4Cl-4)CH(NO_2)CO_2C_2H_5$ (85)	1026
<i>Ethyl</i> cyanoacetate	$(C_2H_5)_2NH$	$NCCH(CO_2C_2H_5)CH(C_6H_4Cl-4)CH(NO_2)CO_2C_2H_5$ (85)	1026
<i>Ethyl</i> nitroacetate §§	$(C_2H_5)_2NH$	$4-ClC_6H_4CH[CH(NO_2)CO_2C_2H_5]_2$ (97)**	154, 1024

Note: References 491-1045 are on pp. 545-555.

** The product was isolated as the *aci*-diethylammonium salt.

§§ The unsaturated ester was formed *in situ* from the ester of nitroacetic acid and the appropriate aldehyde.



Dimethyl malonate	NaOCH ₃	ACH(CO ₂ CH ₃) ₂ (85)	965
Diethyl malonate	NaOC ₂ H ₅	ACH(CO ₂ C ₂ H ₅) ₂ (29)	29, 965
		ACH(CO ₂ C ₂ H ₅) ₂ (two isomers, 87)***	86
Ethyl acetoacetate	NaOC ₂ H ₅	CH ₃ COCH(A)CO ₂ C ₂ H ₅ (42)	29
Ethyl cyanoacetate	NaOC ₂ H ₅	C ₆ H ₅ CH ₂ NO ₂ and C ₆ H ₅ CH=C(CN)CO ₂ C ₂ H ₅ (60)	29
Acetylacetone	NaOC ₂ H ₅	CH ₃ COCH(A)COCH ₃ (11)	29
Phenylacetone	NaOC ₂ H ₅	C ₆ H ₅ CH(A)COCH ₃ (13); C ₆ H ₅ CH ₂ NO ₂ and C ₆ H ₅ CH=C(C ₆ H ₅)COCH ₃	29
Benzoylacetone	NaOC ₂ H ₅	C ₆ H ₅ COCH(A)COCH ₃ (21)	29
Phenylnitromethane†††	CH ₃ NH ₂	C ₆ H ₅ CH(A)NO ₂ ; 1-nitro-1,2,3-triphenyl-1-propene; 3,4,5-triphenylisoxazole	1027
3-Nitro-1,4-diphenyl-3-buten-1-one and			
Dimethyl malonate	NaOCH ₃	C ₆ H ₅ COCH ₂ CH(NO ₂)CH(C ₆ H ₅)CH(CO ₂ CH ₃) ₂ (65)†††	1028

Note: References 491–1045 are on pp. 545–555.

** The product was isolated as the *aci*-diethylammonium salt.

§§ The unsaturated ester was formed *in situ* from the ester of nitroacetic acid and the appropriate aldehyde.

¶¶ The unsaturated ester was formed *in situ* from ethyl nitroacetate and the appropriate ketone.

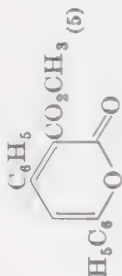
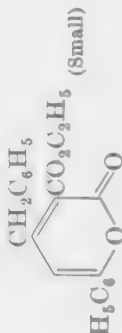
¶¶ This compound was formed *in situ* from pyridine-3-carboxaldehyde and phenylnitromethane.

*** Upon separation of the two isomers, yields of 47 and 17%, respectively, of the pure compounds were obtained.

††† This reaction takes place when benzaldehyde and phenylnitromethane are condensed in the presence of methylamine.

††† This product is obtained at –20°; at –50°, a 30% yield of C₆H₅CH[CH(CO₂CH₃)₂]CH=CHOC₆H₅ is obtained, and at –33–10° of an unidentified product, C₂₀H₁₅NO₄, which gives the same 2,4-dinitrophenylhydrazine as the products obtained at the lower temperature.

TABLE XIX—Continued
MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC NITRO COMPOUNDS

Reactant	Catalyst	Product (Yield, %)	References
β -Nitrobenzylideneacetophenone and Dimethyl malonate	NaOCH_3	 <p>(5)</p>	1029
$C_6H_5COCH=C(NO_2)CH_2C_6H_5$ and Diethyl malonate	NaOCH_3	<p>or</p> $C_6H_5CH=C[CH(CO_2CH_3)_2]COC_6H_5$ (20)  <p>(Small)</p>	1029

Note: References 491–1045 are on pp. 545–555.

TABLE XX

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC SULFONES			References
Reactants	Catalyst	Product (Yield, %)	
<i>Methyl Vinyl Sulfone and</i>			
$A = \text{CH}_3\text{SO}_2\text{CH}_2\text{CH}_2-$			
Diethyl malonate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(A)_2\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (61)	118
Diethyl phenylmalonate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{AC}(\text{C}_6\text{H}_5)(\text{CO}_2\text{C}_2\text{H}_5)_2$ (58)	118
Ethyl acetoacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{COC}(A)_2\text{CO}_2\text{C}_2\text{H}_5$ (70)	118
Ethyl cyanoacetate	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{NCC}(A)_2\text{CO}_2\text{C}_2\text{H}_5$ (81)	118
Benzyl cyanide	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{NCC}(A)_2\text{C}_6\text{H}_5$ (68)	118
Acetylacetone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{CH}_3\text{COC}(A)_2\text{COCH}_3$ (36), $\text{CH}_3\text{COCH}(A)_2$ (24)	118
Phenylacetone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_6\text{H}_5\text{CH}(A)\text{COCH}_3$ (61)	118
Nitromethane	Aq. KOH	$(A)_3\text{CNO}_2$ (50)	1030
<i>p</i> -Bromophenylnitromethane	$[\text{CH}_3\text{N}(\text{C}_2\text{H}_5)_3]\text{OH}$	<i>p</i> -BrC ₆ H ₄ CH(A)NO ₂ (50)	1030
Phenacyl <i>p</i> -tolyl sulfone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$\text{C}_6\text{H}_5\text{COCH}(A)\text{SO}_2\text{C}_6\text{H}_4\text{CH}_3$ - <i>p</i> (61)	118
Bisbenzenesulfonylmethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(A)_2\text{C}(\text{SO}_2\text{C}_6\text{H}_5)_2$ (82)	118
Bismethanesulfonylmethane	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	$(A)_2\text{C}(\text{SO}_2\text{CH}_3)_2$ (84)	118
<i>Vinyl n-Butyl Sulfone and</i>			
$A = n\text{-C}_4\text{H}_9\text{SO}_2\text{CH}_2\text{CH}_2-$			
Nitroethane	Aq. NaOH	$\text{ACH}(\text{CH}_3)\text{NO}_2$ (45), $(A)_2\text{C}(\text{CH}_3)\text{NO}_2$ (13)	1030
	Aq. KOH	$(A)_2\text{C}(\text{CH}_3)\text{NO}_2$ (75)	1030
1-Nitropropane	Aq. NaOH	$\text{ACH}(\text{C}_2\text{H}_5)\text{NO}_2$ and $\text{A}_2\text{C}(\text{C}_2\text{H}_5)\text{NO}_2$ (16)	1030
<i>Vinyl Isobutyl Sulfone and</i>			
<i>p</i> -Bromophenylnitromethane	NaOH	<i>i</i> -C ₄ H ₉ SO ₂ CH ₂ CH ₂ CH(NO ₂)C ₆ H ₄ Br- <i>p</i> (30)	1030
<i>Divinyl Sulfone and</i>			
2-Nitropropane	Aq. KOH	$\text{O}_2\text{S}[(\text{CH}_2\text{CH}_2\text{C}(\text{CH}_3)_2\text{NO}_2)_2]$	1030

Note: References 491-1045 are on pp. 545-555.

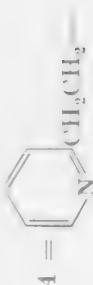


TABLE XX—Continued

MICHAEL CONDENSATIONS WITH α,β -ETHYLENIC SULFONES			References
Reactants	Catalyst	Product (Yield, %)	
<i>Vinyl p-Tolyl Sulfone and</i>		$A = p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{CH}_2\text{CH}_3$ —	
Nitromethane	NaOCH ₃	(A) ₂ CHNO ₂ (91)	1031
1-Nitropropane	Aq. KOH	(A) ₂ C(C ₂ H ₅)NO ₂	1030
2-Nitropropane	Aq. KOH	(CH ₃) ₂ C(A)NO ₂	1030
<i>Phenyl Styryl Sulfone and</i>			
Diethyl malonate	Na	C ₆ H ₅ SO ₂ CH ₂ CH(C ₆ H ₅)CH(CO ₂ C ₂ H ₅) ₂ (97)	1031
<i>p-Tolyl Styryl Sulfone and</i>			
Diethyl malonate	Na	$p\text{-CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{CH}_2\text{CH}(\text{C}_6\text{H}_5)\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (quant.)	1032
<i>Distyryl Sulfone and</i>			
Diethyl malonate	Na	O ₂ S[CH ₂ CH(C ₆ H ₅)CH(CO ₂ C ₂ H ₅) ₂] ₂ (74)	1033
<i>Vinylsulfonic Acid N-Ethylanilide and</i>		$A = \text{CH}_2\text{CH}_2\text{SO}_2\text{N}(\text{C}_2\text{H}_5)\text{C}_6\text{H}_5$	
Nitromethane	KOH, CH ₃ OH	(A) ₂ CNO ₂ (38-48)	358
	Excess KOH, CH ₃ OH	(A) ₂ CHNO ₂ (18)	358
Nitroethane	KOH, CH ₃ OH	(A) ₂ C(NO ₂)CH ₃ (18-61), ACH(NO ₂)CH ₃ (31-44)	358
1-Nitropropane	KOH, CH ₃ OH	(A) ₂ C(NO ₂)CH ₂ CH ₃ (31), ACH(NO ₂)CH ₂ CH ₃ (35-40)	358
2-Nitropropane	KOH, CH ₃ OH	(CH ₃) ₂ C(A)NO ₂ (83)	358
<i>Vinyltrimethylsulfonium Bromide and</i>			
Diethyl malonate	Aq. NaOH	3,3-Dicarboethoxypropyldimethylsulfonium salt (48)	22
Methyl acetate	Aq. NaOH	(3-Acetyl-3-carboethoxypropyldimethylsulfonium bromide (68)	22

Note: References 491-1045 are on pp. 545-555.

TABLE XXI


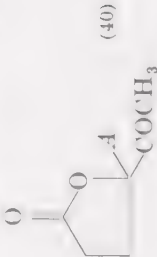
MICHAEL CONDENSATIONS WITH 2- AND 4-VINYLPYRIDINE, WITH ANALOGS OF 2-VINYLPYRIDINE, AND WITH DIETHYL VINYLPHOSPHONATE


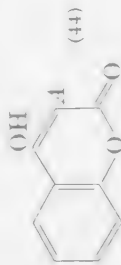
Donor	Catalyst	Product (Yield, %)	References
<i>4. 2-Vinylpyridine</i>			
Diethyl malonate	Na NaOC ₂ H ₅	$A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (53) $A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (84, 42-43, 62)	1034 1035, 1036, 1037
	Na Na [C ₆ H ₅ CH ₂ N(CH ₃) ₃]OH	(A) ₂ C(CO ₂ C ₂ H ₅) ₂ (42-43) AC(C ₂ H ₅)(CO ₂ C ₂ H ₅) ₂ (39) (CH ₃) ₂ C(A)(CO ₂ C ₂ H ₅) (48) C ₆ H ₅ CH(A)(CO ₂ C ₂ H ₅)	1037, 1035 1035 1038 1038
Diethyl ethylmalonate Ethyl isobutyrate Ethyl phenylacetate	NaOC ₂ H ₅		1039, 1040
Ethyl 2-pyridylacetate	NaOC ₂ H ₅	 (41, 61)	1034, 1035 1038
Ethyl acetoacetate Ethyl <i>n</i> -butylacetoacetate	Na; NaOC ₂ H ₅ Na	CH ₃ COCH(A)CO ₂ C ₂ H ₅ (58, 50) CH ₃ COC(C ₄ H ₉ - <i>n</i>)(A)CO ₂ C ₂ H ₅ (3)	1034, 1035 1038
2-Carboxycyclopentanone	Na	 (42)	1041

Note: References 491-1045 on are pp. 545-555.

TABLE XXI—Continued

A. 2-Vinylpyridine—Continued

Donor	Catalyst	Product (Yield, %)	References
		$A = $ 	
Ethyl benzoylacetate	Na $[(C_6H_5CH_2N(CH_3)_3)OH]$	$C_6H_5COCH(A)CO_2C_2H_5$ (70) $(C_6H_5COCH(A)CO_2C_2H_5)$	490 1038
γ -Acetyl- γ -butyrolactone	Na	 (40)	490
Ethyl cyanoacetate	Na	$ACH(CN)CO_2C_2H_5$ (48)	798
Propionitrile	Na	$CH_3CH(A)CN$ (19); $CH_3C(A)_2CN$ (39)	1038
Benzyl cyanide	Na	$C_6H_5CH(A)CN$ (77)	798
Methyl ethyl ketone	None $[(C_6H_5CH_2N(CH_3)_3)OH]$ Na	$(CH_3CH(A)COCH_3)$ $CH_3CH(A)COCH_3$ (53), $CH_3C(A)_2COCH_3$ (31) $CH_3COCH(A)CH_3$ (71), $CH_3COC(A)_2CH_3$ (31), A $CH_2COC(A)_2CH_3$ (16)	1042 1038 1038
Isobutyl ketone	Na	$CH_3CH_2COCH(A)CH_3$ (53), $CH_3CH_2COC(A)_2CH_3$ (32)	1038
Acetylacetone	$NaOC_2H_5$	$CH_3COCH(A)COCH_3$ (16), $CH_3COC(A)_2COCH_3$ (7)	1035
Methyl isopropyl ketone	Na	$CH_3COC(A)(CH_3)_2$ (65), A $CH_2COC(A)(CH_3)_2$ (31), $(A)_2CHCOC(A)(CH_3)_2$ (39)	1038
Methyl isobutyl ketone	Na	$CH_3COCH(A)CH(CH_3)_2$ (20) $CH_3COC(A)_2CH(CH_3)_2$ (34), A $CH_2COC(A)_2CH(CH_3)_2$ (13)	1038


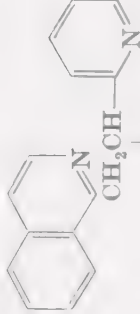
Diisopropyl ketone	Na	$(\text{CH}_3)_2\text{CHCOCH(A)}(\text{CH}_3)_2$ (72), $(\text{CH}_3)_2\text{C(A)}(\text{COCH(A)})(\text{CH}_3)_2$ (5)	1038
Methyl <i>n</i> -amyl ketone	Na	$\text{CH}_3\text{COCH(A)}\text{C}_4\text{H}_9\text{-}n$ (39), $\text{CH}_3\text{COC(A)}_2\text{C}_4\text{H}_9\text{-}n$ (19)	1038
Diisobutyl ketone	Na	$\text{CH}_3\text{COCH(A)}\text{C}_4\text{H}_9\text{-}n$ (3)	1038
		$(\text{CH}_3)_2\text{CHCH}_2\text{COCH(A)}\text{CH}(\text{CH}_3)_2$ (63), $(\text{CH}_3)_2\text{CHCH}_2\text{COC(A)}_2\text{CH}(\text{CH}_3)_2$ (14)	
2,5,6-Trimethyl-4-hepten-3-one*	Na	$(\text{CH}_3)_2\text{C(A)}\text{COCH}=\text{C}(\text{CH}_3)\text{CH}(\text{CH}_3)_2$ (29)	1038
Acetophenone	Na	$\text{C}_6\text{H}_5\text{COCH}_2\text{A}$ (8), $\text{C}_6\text{H}_5\text{COCH(A)}_2$ (53)	1038
Phenylacetone	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH}_2\text{A}$ (11)	1041
	Na	$\text{CH}_3\text{COCH(A)}\text{C}_6\text{H}_5$ (32)	1038
Propiophenone	Na	$\text{CH}_3\text{COCH(A)}\text{C}_6\text{H}_5$ (44)	1038
	Na	$\text{C}_6\text{H}_5\text{COCH(A)}\text{CH}_3$ (43), $\text{C}_6\text{H}_5\text{COC(A)}_2\text{CH}_3$ (45)	1038
Deoxybenzoin	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$ NaOC_2H_5	$\text{C}_6\text{H}_5\text{COCH(A)}\text{CH}_3$ (59)	1041
		$\text{C}_6\text{H}_5\text{COCH(A)}\text{C}_6\text{H}_5$ (46)	
2-Acetylfuran	$[\text{C}_6\text{H}_5\text{CH}_2\text{N}(\text{CH}_3)_3]\text{OH}$	 (5)	1038
2-Picoline	Na	1,3-Di-(α -pyridyl)propane (33)	454
4-Hydroxycoumarin	Na	 (44)	490

Note: References 491-1045 are on pp. 545-555.

* This ketone was formed and reacted when methyl isopropyl ketone was brought together with sodium metal and 2-vinylpyridine.

TABLE XXI—Continued

A. 2-Vinylpyridine—Continued

Donor	Catalyst	Product (Yield, %)	References
3-Methyl-4-hydroxycoumarin	Na	 (90)	490
1-Cyano-2-benzoyl-1,2-dihydro-isoquinoline	Li salt	 (50)	805a

B. 4-Vinylpyridine

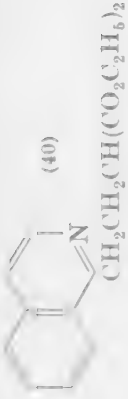
Ethyl benzoylacetate γ -Picoline	Na K	1-Benzoyl-3-(γ -pyridyl)propane (51)† 1,3-Di-(γ -pyridyl)propane (44)	1041 484
--	---------	--	-------------

C. Analogs of 2-Vinylpyridine

2-Vinylquinoline† and			
Ethyl malonate	NaOC ₂ H ₅	$A\text{CH}(\text{CO}_2\text{C}_2\text{H}_5)_2$ (43)	1043
Ethyl acetoacetate	NaOC ₂ H ₅	$\text{CH}_3\text{C}(\text{OC}(\text{H})(A)\text{CO}_2\text{C}_2\text{H}_5)$ (44)	1043
Ethyl benzoylacetate	NaOC ₂ H ₅	$\text{C}_6\text{H}_5\text{COC}(\text{H})(A)\text{CO}_2\text{C}_2\text{H}_5$ (33)	1043

Diethyl malonate

NaOC₂H₅



D. Diethyl Vinylphosphonate¹⁰⁴⁵

Catalyst NaOC₂H₅



Donor	Product (Yield, %)
Diethyl malonate	$4CH(CO_2C_2H_5)_2$ (80)
Diethyl methylmalonate	$(CH_3C(A)(CO_2C_2H_5)_2)_2$ (79)
Diethyl ethylmalonate	$(C_2H_5C(A)(CO_2C_2H_5)_2)_2$ (59)
Diethyl n-propylmalonate	$n-C_3H_7C(A)(CO_2C_2H_5)_2$ (78)
Diethyl n-butylmalonate	$n-C_4H_9C(A)(CO_2C_2H_5)_2$ (86)
Ethyl acetoacetate	$CH_3COCH(A)CO_2C_2H_5$ (15)
Ethyl n-propylacetoacetate	$CH_3COC(A)(C_3H_7-n)CO_2C_2H_5$ (16)
Ethyl cyanoacetate	$N(C(A)CO_2C_2H_5)_2$ (16); $N(C(A)_2CO_2C_2H_5)_2$ (18)
Ethyl methylcyanoacetate	$NCC(A)(CH_3)CO_2C_2H_5$ (89)
Ethyl ethylcyanoacetate	$NCC(A)(C_2H_5)CO_2C_2H_5$ (66)
Ethyl isopropylcyanoacetate	$N(C(A)(C_3H_7-i)CO_2C_2H_5)_2$ (84)
Ethyl n-butylcyanoacetate	$NCC(A)(C_4H_9-n)CO_2C_2H_5$ (78)
Benzyl cyanide	$C_6H_5C(A)_2CN$ (8)

Note: References 491–1045 are on pp. 545–555.

† This product is obtained after hydrolysis and decarboxylation.

‡ This compound was formed *in situ* from 2-(β -diethylaminoethyl)quinoline methosulfate.

§ When this compound was formed *in situ* from 1-(β -dimethylaminoethyl)isoquinoline methiodide, a more complex reaction product was obtained.

TABLE XXII

DONORS USED IN MICHAEL CONDENSATIONS

Malonates, $RCH(CO_2C_2H_5)_2$: $R = H, Cl, Br, NO_2$, methyl, ethyl, *n*-propyl, *n*-butyl, *n*-hexyl, *n*-octyl, *n*-decyl, *n*-dodecyl, *n*-tetradecyl, *n*-hexadecyl, β -methoxyethyl, β -ethoxyethyl, phenyl, benzyl, phenethyl, 1-naphthyl, 1-naphthylmethyl, β -(1-naphthylethyl), 2-naphthyl, 2-naphthylmethyl, β -(2-naphthylethyl); β -aldehydoethyl, β -aldehydopropyl, acetoxy, formamido, acetamido, phthalimido, $R'O_2CCH_2-$, $(R'O_2C)_2CH-$, $R'O_2CCH(CH_3)-CH(CO_2R')$, $CH_2=C(CO_2C_2H_5)-$, β -ionylideneacetyl, isobutyryl.

Dibenzyl malonate, malonamide, ethyl malonamate, ethyl malonamidinate, diethyl α -cyano- β -methylsuccinate, diethyl α -cyano- β , β -dimethylglutarate.

Cyanoacetates, $RCH(CN)CO_2C_2H_5$: $R = H$, methyl, ethyl, isopropyl, *n*-butyl, phenyl, phenethyl, β -aldehydoethyl, acetamido, $R'O_2C(CH_2)_3-C(CH_3)(CN)-$.

Acetoacetates, $CH_3COCHRCO_2C_2H_5$: $R = H$, methyl, ethyl, *n*-propyl, isopropyl, *n*-butyl, isomyl, hexyl, phenyl, benzyl, allyl; acetoacetanilide. Ethyl iminoacetoacetate, $CH_3C(=NH)CH_2CO_2C_2H_5$, and its *N*-methyl derivative; ethyl iminomethylacetoacetate, $CH_3C(=NH)CH(CH_3)CO_2C_2H_5$.

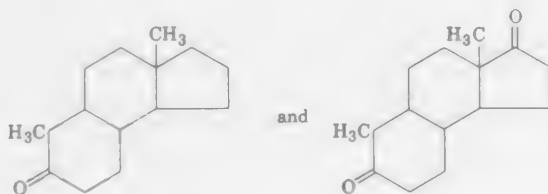
Other ketonic esters: ethyl propionylacetate, butyrylacetate, isobutyrylacetate, hexanoylacetate, γ -ethoxyacetoacetate, palmitoylacetate, stearoylacetate; diethyl acetone-1,3-dicarboxylate, ethyl isobutyrylisobutyrate, ethyl α -acetylsuccinate, ethyl α -acetyladipate, $C_2H_5O_2CCH_2CH_2COCH(CH_3)CO_2C_2H_5$, ethyl benzoylacetate, ethyl 2-oxocyclohexane-1-carboxylate and its 3-methyl derivative, ethyl 2-oxocyclopentane-1-carboxylate and its 5-methyl derivative, higher cycloalkanone-2-carboxylates, 2-carbomethoxy-1-tetralone, methyl 1-keto-1,2,3,4-tetrahydrophenanthrene-2-carboxylate, ethyl camphor-3-carboxylate, 3-ethoxy-5,5-dimethyl-6-carbethoxy-2-cyclohexen-1-one, ethyl phenylpyruvate (α -keto ester).

Monocarboxylic acid esters: ethyl acetate, ethyl isobutyrate, diethyl glutaconate, diethyl itaconate, ethyl phenylacetate (also *m*- NO_2 , *p*- NO_2 , Cl , Br , and C_2H_5 analogs) and its α -ethyl, *n*-propyl, *n*-butyl, isobutyl derivatives, ethyl furan-2-acetate, ethyl thiophene-2-acetate, ethyl α -naphthylacetate, methyl diphenylacetate, ethyl α -pyridylacetate, triethyl phosphonoacetate, triethyl α -phosphonohexanoate.

Ketones: acetone, methyl ethyl ketone, methyl *n*-propyl ketone,* methyl isopropyl ketone,* methyl isobutyl ketone,* pinacolone, methyl *n*-butyl ketone,* methyl *n*-amyl ketone,* diisopropyl ketone,* diisobutyl ketone, isopropyl *n*-amyl ketone,* isopropyl *n*-nonyl ketone,* methyl β -cyanoethyl ketone, β , β -diethoxyethyl alkyl ketones, acetylacetone, acetonylacetone,* heptadecane-2,4-dione, octadecane-2,4-dione, isobutyrylacetone, diisobutyrylmethane, cyclopentanone, 2-methylcyclopentane-1,3-dione, cyclohexanone,

* Condensed only with acrylonitrile as acceptor.

2-, 3-, and 4-methylcyclohexanone, carvenone, dihydro- and tetrahydrocarvone, carvotanacetone, cyclohexane-1,2-dione, 2-hydroxy- and 2-acetoxycyclohexanone, cyclohexane-1,3-dione and its 2-alkyl derivatives, 5,5-dimethyl-1,3-cyclohexanedione, cyclohexenylcyclohexanone, 2-methyl-6-isopropenylcyclohexanone, 2-aldehydocyclohexanone, 2-aldehyde-4-(*p*-carboxy- and *p*-carbomethoxy-cyclohexyl)cyclohexanone, higher cycloalkanones, 1-tetralone, 2-methyl-1-tetralone, 6-methoxy-1-tetralone, 2-(β -diethylaminoethyl)-1-tetralone, 2-hydroxymethylene-6-methoxy-1-tetralone, *trans*-2-decalone, 1-methyl-2-decalone (*cis* and *trans*) and its 5-methoxy, 6-methoxy, 5,6-dimethoxy, and 6-carbethoxy derivatives, 10-methyl-2-decalone, 9-methyl-8-hydrindanone, anthrone, 4-keto-1,2,3,4-tetrahydropheanthrene, 4-keto-1,2,3,4,9,10,11,12-octahydropheanthrene,* 4,9-diketo-1,2,3,4,9,10,11,12-octahydropheanthrene,*



Acetophenone, phenylacetone, propiophenone, isobutyrophenone, benzoylacetone, dibenzyl ketone, deoxybenzoin, *p*-phenylacetyl biphenyl, dibenzoylmethane, 1,2-dibenzoyl ethane, α -methyl- α -*n*-butylacetophenone,* α -methyl- α -*n*-octylacetophenone,* α -ethyl- α -*n*-propylacetophenone,* isopropyl benzyl ketone,* α -phenyl- α -*n*-octylacetone,* 2-phenylcyclohexanone and its 6-benzylidene derivative,* 2-aldehyde-4-(*p*-carboxy- and *p*-carbomethoxyphenyl)cyclohexanone, 2-phenylcycloheptanone.

2-Acetylfuran,* 5-methyl-2-acetylfuran,* 2-propionylfuran,* 5-methyl-2-propionylfuran,* 2,5-dimethyl-3-acetylfuran,* 2,5-dimethyl-3-propionylfuran,* 2-butyrylfuran,* 2,5-dimethyl-3-butyrylfuran,* 2-acetyl-, 2-propionyl-, and 2-butyryl-thiophene and their 5-methyl derivatives,* 2-acetoacetylthiophene.*

Acetylacetone imine, benzoylacetone imine, (*p*-methylbenzoyl)acetone imine.

Aldehydes: acetaldehyde,* propionaldehyde,* butyraldehyde, isobutyraldehyde, diethylacetaldehyde,* heptaldehyde, 2-ethylhexanal, diethylacetaldehyde, phenylacetaldehyde, α -phenylpropionaldehyde.*

Nitriles: malononitrile, acetonitrile, propionitrile, cyanoacetamide and its *N*-alkyl derivatives, benzyl cyanide and its derivatives nuclearly substituted by α -Cl, m -Cl, Br, CH₃, NH₂, *p*-Br, CH₃, OCH₃, NO₂; benzyl cyanide α -substituted by methyl, ethyl, isopropyl, *n*-butyl, *n*-pentyl, 3-methylbutyl, (1-cyclohexenyl), cyclohexyl, (*p*-chlorophenyl), (2-thienyl), (2-pyridyl) and β -diethylaminoethyl; diphenylacetonitrile; diethyl cyanomethane phosphonate, 2-cyanocycloheptanone, CH₃Cl—NHCH₂CN, C₆H₅Cl—NHCH₂CN.

* Condensed only with acrylonitrile as acceptor.

TABLE XXII—*Continued*

DONORS USED IN MICHAEL CONDENSATIONS

Nitro compounds: nitromethane, nitroethane, 1-nitropropane, 2-nitropropane, 1-nitrobutane, 1-nitroisobutane, β,β -dinitroethanol, methyl 2-nitropropyl ether, methyl 2-nitropropyl sulfide, butyl 3-nitrobutyl sulfone, nitrocyclohexane, dinitromethane, phenylnitromethane and its *p*-bromo derivative, methyl 2-nitro-1-phenylpropyl ether, methyl and ethyl nitroacetates, methyl γ,γ -dinitrobutyrate, diethyl nitromalonate, 1,1-dinitroethane.

Sulfones: phenyl benzyl sulfone, *p*-tolyl benzyl sulfone, allyl *p*-tolyl sulfone, ethyl *p*-toluenesulfoacetate, phenacyl *p*-tolyl sulfone, bis(benzenesulfonyl)methane, bis(methanesulfonyl)methane.

Hydrocarbons and derivatives: cyclopentadiene, divinylmethane, indene, 1-isopropylideneindene, fluorene, 2-nitrofluorene,* 2,7-dibromofluorene, 1-methylfluorene, 9-phenylfluorene, 9-hydroxyfluorene, fluorene-9-carboxylates, ethyl 1-methylfluorene-9-carboxylate, 1,2,3,4-tetrahydrofluoranthene, 2,3,4-trimethyl-1,2-dihydrofluoranthene, 4,5-methylenephenanthrene, methyl 4-cyclopenta[*def*]phenanthrene-4-carboxylate.

Miscellaneous donors (of occasional use): α -aceto- γ -butyrolactone, ethyl oxaloacetate and its α -methyl derivative, ethyl β -methyl- γ -nitrobutyrate, diethyl succinate, isophorone, 1-formyl-2-keto-10-methyl- $\Delta^{3,6}$ -hexahydronaphthalene, α -naphthol (keto form), ethyl 4-hydroxy-2,3-benzofuran-5-carboxylate (keto form), 4-hydroxycoumarin (keto form), 2-hydroxy-1,4-naphthoquinone (keto form), 2-acetyl-5-cyclohexan-1-one, ethyl (3,4-dihydro-1-naphthyl)cyanoacetate, ethyl (1-methyl-1,2,5,6-tetrahydro-4-pyridyl)acetate, α - and γ -picoline, α - and γ -quinaldine, rhodanine, Inhoffen ketone, kojic acid, 1-methyloxindole, 1,3-dimethyloxindole, methyl oxindole-3-propionate, 2,3-dihydro-2-phenylbenzo- γ -pyrone.

* Condensed only with acrylonitrile as acceptor.

REFERENCES FOR TABLES I-XXII

- ⁴⁸⁷ Warner and Moe, U.S. pat. 2,520,666 [*C.A.*, **45**, 643 (1951)].
- ⁴⁸⁸ Warner and Moe, U.S. pat. 2,575,375 [*C.A.*, **46**, 5081 (1952)].
- ⁴⁸⁹ Moe and Warner, U.S. pat. 2,540,053 [*C.A.*, **45**, 5720 (1951)].
- ⁴⁹⁰ Warner and Moe, U.S. pat. 2,523,746 [*C.A.*, **45**, 5719 (1951)].
- ⁴⁹¹ Warner and Moe, U.S. pat. 2,523,743 [*C.A.*, **45**, 5718 (1951)].
- ⁴⁹² Yamada, Chibata, and Tsurui, *J. Pharm. Soc. Japan*, **73**, 123 (1953) [*C.A.*, **47**, 11132 (1953)].
- ⁴⁹³ Warner and Moe, U.S. pat. 2,546,958 [*C.A.*, **45**, 8035 (1951)].
- ⁴⁹⁴ Jacquier, Zagdoun, and Fontaine, *Bull. soc. chim. France*, **1953**, 25.
- ⁴⁹⁵ Mousseron, Jacquier, Fontaine, and Zagdoun, *Bull. soc. chim. France*, **1954**, 1246.
- ⁴⁹⁶ Moe and Warner, U.S. pat. 2,610,204 [*C.A.*, **47**, 5961 (1953)].
- ⁴⁹⁷ Jacquier and Fontaine, *Bull. soc. chim. France*, **1952**, 248.
- ⁴⁹⁸ Warner and Moe, U.S. pat. 2,532,047 [*C.A.*, **45**, 2971 (1951)].
- ⁴⁹⁹ Warner and Moe, U.S. pat. 2,532,048 [*C.A.*, **45**, 2971 (1951)].
- ⁵⁰⁰ Moe and Warner, U.S. pat. 2,551,566 [*C.A.*, **46**, 133 (1952)].
- ⁵⁰¹ Smith, U.S. pat. 2,516,729 [*C.A.*, **45**, 6217 (1951)].
- ⁵⁰² Shechter, Ley, and Zeldin, *J. Am. Chem. Soc.*, **74**, 3664 (1952).
- ⁵⁰³ Warner and Moe, *J. Am. Chem. Soc.*, **74**, 1064 (1952).
- ⁵⁰⁴ N.V. de Bataafsche Petroleum Maatschappij, Brit. pat. 666,623 [*C.A.*, **46**, 11230 (1952)].
- ⁵⁰⁵ Moe and Warner, U.S. pat. 2,599,653 [*C.A.*, **47**, 3339 (1953)].
- ⁵⁰⁶ Moe and Warner, U.S. pat. 2,546,960 [*C.A.*, **45**, 8036 (1951)].
- ⁵⁰⁷ Moe and Warner, U.S. pat. 2,540,054 [*C.A.*, **45**, 5720 (1951)].
- ⁵⁰⁸ Mukherjee and Bhattacharyya, *J. Indian Chem. Soc.*, **23**, 451 (1946) [*C.A.*, **42**, 128 (1948)].
- ⁵⁰⁹ Distillers Company Ltd., British pat. 706,176 [*C.A.*, **49**, 9030 (1955)].
- ⁵¹⁰ Dornow and Karlson, *Ber.*, **73**, 542 (1940).
- ⁵¹¹ Baumgarten and Dornow, *Ber.*, **72**, 563 (1939).
- ⁵¹² Fischer and Hultsch, *Ber.*, **68**, 1726 (1935).
- ⁵¹³ Weizmann, Brit. pat. 594,182 [*C.A.*, **42**, 2986 (1948)].
- ⁵¹⁴ Weizmann, U.S. pat. 2,472,135 [*C.A.*, **43**, 6664 (1949)].
- ⁵¹⁵ Moe and Warner, U.S. pat. 2,523,710 [*C.A.*, **45**, 5717 (1951)].
- ⁵¹⁶ Moe and Warner, U.S. pat. 2,628,980 [*C.A.*, **48**, 724 (1954)].
- ⁵¹⁷ Dornow and Hargesheimer, *Chem. Ber.*, **86**, 461 (1953).
- ⁵¹⁸ Kress, U.S. pat. 2,540,267 [*C.A.*, **45**, 5720 (1951)].
- ⁵¹⁹ Ise-oka, *Bull. Inst. Chem. Research, Kyoto Univ.*, **31**, 190 (1953) [*C.A.*, **49**, 6183 (1955)].
- ⁵²⁰ Rhinesmith, *J. Am. Chem. Soc.*, **58**, 596 (1936).
- ⁵²¹ Nazarov and Zav'yalov, *Izvest. Akad. Nauk S.S.S.R. Otdel. Khim. Nauk*, **1952**, 300 [*C.A.*, **47**, 5364 (1953)].
- ⁵²² Boehme and Mundlos, *Chem. Ber.*, **86**, 1414 (1953).
- ⁵²³ Walker, *J. Chem. Soc.*, **1935**, 1585.
- ⁵²⁴ Wieland and Miescher, *Helv. Chim. Acta*, **33**, 2215 (1950); cf. Miescher and Wieland *ibid.*, **33**, 1847 (1950).
- ⁵²⁵ Dauben, Tweit, and MacLean, *J. Am. Chem. Soc.*, **77**, 48 (1955).
- ⁵²⁶ Dreiding and Tomasewski, *J. Am. Chem. Soc.*, **77**, 411 (1955).
- ⁵²⁷ Stork, *Bull. soc. chim. France*, **1955**, 256.
- ⁵²⁸ Wilds and Werth, *J. Org. Chem.*, **17**, 1149 (1952).
- ⁵²⁹ Wilds and Werth, *J. Org. Chem.*, **17**, 1154 (1952).
- ⁵³⁰ Chem. Werke Huels, Ger. pat. 833,645 [*C.A.*, **47**, 2205 (1953)].
- ⁵³¹ Stork, Terrell, and Szmuszkowicz, *J. Am. Chem. Soc.*, **76**, 2029 (1954).
- ⁵³² Walker, *J. Am. Chem. Soc.*, **77**, 3664 (1955).
- ⁵³³ Rabin, Waldman, Moshell, and Wills, U.S. pat. 2,674,637 [*C.A.*, **49**, 1813 (1955)].
- ⁵³⁴ Nazarov and Zav'yalov, *Zhur. Obshchei Khim.*, **23**, 1703 (1949) [*C.A.*, **48**, 13667 (1954)].

- ⁵⁴⁹ Wendler and Slates, U.S. pat. 2,542,223 [C.A., **45**, 7599 (1951)].
⁵⁴⁰ Poos, Arth, Beyler, and Sarett, *J. Am. Chem. Soc.*, **75**, 422 (1953).
⁵⁴¹ Sarett and Beyler, U.S. pat. 2,617,828 [C.A., **47**, 9365 (1953)].
⁵⁴² Wieland, Ueberwasser, Anner, and Miescher, *Helv. Chim. Acta*, **36**, 1231 (1953).
⁵⁴³ British Celanese Ltd., Brit. pat. 671,412 [C.A., **47**, 2198 (1953)].
⁵⁴⁴ Stubbs and Tucker, *J. Chem. Soc.*, **1950**, 3288.
⁵⁴⁵ Dannenberg and Dannenberg-von Dresler, *Ann.*, **593**, 232 (1955).
⁵⁴⁶ Leonard and Simon, *J. Org. Chem.*, **17**, 1262 (1952).
⁵⁴⁷ Mariella, *Org. Syntheses*, **32**, 32 (1952).
⁵⁴⁸ Wilds and Djerassi, *J. Am. Chem. Soc.*, **68**, 1715 (1946).
⁵⁴⁹ Blaise and Maire, *Bull. soc. chim. France*, [4], **3**, 421 (1908).
⁵⁵⁰ Blaise and Maire, *Bull. soc. chim. France*, [4], **3**, 413 (1908).
⁵⁵¹ Woodward, Sondheimer, Taub, Heusler, and McLamore, *J. Am. Chem. Soc.*, **74**, 4223 (1952).
⁵⁵² Dreux, *Bull. soc. chim. France*, **1954**, 1443.
⁵⁵³ van Wagtenonk and Wibaut, *Rec. trav. chim.*, **61**, 728 (1942).
⁵⁵⁴ Mariella and Leech, *J. Am. Chem. Soc.*, **71**, 331 (1949).
⁵⁵⁵ Guareschi, *Chem. Zentr.*, **1899**, **I**, 289.
⁵⁵⁶ Moir, *J. Chem. Soc.*, **81**, 113 (1902).
⁵⁵⁷ Basu, *J. Indian Chem. Soc.*, **12**, 289 (1935) [C.A., **29**, 6891 (1935)].
⁵⁵⁸ Steiner and Willhalm, *Helv. Chim. Acta*, **35**, 1752 (1952).
^{559a} Stobbe, *Ber.*, **34**, 1955 (1901).
⁵⁵⁹ Qudrat-I-Khuda, *J. Chem. Soc.*, **1929**, 201.
⁵⁶⁰ Smith and Engelhardt, *J. Am. Chem. Soc.*, **71**, 2671, 2676 (1949).
⁵⁶¹ France, Maitland, and Tucker, *J. Chem. Soc.*, **1937**, 1739.
⁵⁶² Prelog, Komzak, and Moor, *Helv. Chim. Acta*, **25**, 1654 (1942).
⁵⁶³ Oparina, *Ber.*, **64**, 569 (1931).
⁵⁶⁴ Kochetkov, *Doklady Akad. Nauk S.S.S.R.*, **84**, 289 (1952) [C.A., **47**, 3309 (1953)].
⁵⁶⁵ Eccott and Linstead, *J. Chem. Soc.*, **1930**, 905.
⁵⁶⁶ Qudrat-I-Khuda, *J. Chem. Soc.*, **1929**, 1913.
⁵⁶⁷ Frank and Hall, Jr., *J. Am. Chem. Soc.*, **72**, 1645 (1950).
⁵⁶⁸ Crossley, *Proc. Chem. Soc.*, **17**, 172 (1901).
⁵⁶⁹ Bardhan, *J. Chem. Soc.*, **1928**, 2604.
⁵⁷⁰ Kon and Linstead, *J. Chem. Soc.*, **127**, 815 (1925).
⁵⁷¹ Kon and Leton, *J. Chem. Soc.*, **1931**, 2496.
⁵⁷² Birch and Robinson, *J. Chem. Soc.*, **1942**, 488.
⁵⁷³ Allen and Cressman, *J. Am. Chem. Soc.*, **55**, 2953 (1933).
⁵⁷⁴ Abdullah, *J. Indian Chem. Soc.*, **12**, 62 (1935) [C.A., **29**, 3995 (1935)].
⁵⁷⁵ Allen and Barker, *J. Am. Chem. Soc.*, **54**, 736 (1932).
⁵⁷⁶ Allen and Bridgess, *J. Am. Chem. Soc.*, **51**, 2151 (1929).
⁵⁷⁷ Walker, *J. Chem. Soc.*, **1939**, 120.
⁵⁷⁸ Rosenmund, Herzberg, and Schütt, *Chem. Ber.*, **87**, 1258 (1954).
⁵⁷⁹ Vorlaender, *Ber.*, **27**, 2053 (1894).
⁵⁸⁰ Gohdes, *J. prakt. Chem.*, [2], **123**, 169 (1929).
⁵⁸¹ Albertson, *J. Am. Chem. Soc.*, **72**, 2594 (1950).
⁵⁸² Baddar and Warren, *J. Chem. Soc.*, **1939**, 944.
⁵⁸³ Zaugg, *J. Am. Chem. Soc.*, **71**, 1890 (1949).
⁵⁸⁴ Seidman, Robertson, and Link, *J. Am. Chem. Soc.*, **72**, 5193 (1950).
⁵⁸⁵ Starr and Haber, U.S. pat. 2,666,064 [C.A., **49**, 380 (1955)].
⁵⁸⁶ Kuhn and Weiser, *Chem. Ber.*, **88**, 1601 (1955).
⁵⁸⁷ Hinkel, Ayling, and Dippy, *J. Chem. Soc.*, **1935**, 539.
⁵⁸⁸ Horning and Field, *J. Am. Chem. Soc.*, **68**, 387 (1946).
⁵⁸⁹ Friedmann, *J. prakt. Chem.*, [2], **146**, 71 (1936).
⁵⁹⁰ Hinkel and Dippy, *J. Chem. Soc.*, **1930**, 1387.
⁵⁹¹ Barat, *J. Indian Chem. Soc.*, **8**, 699 (1931) [C.A., **26**, 1608 (1932)].
⁵⁹² Basu, *J. Indian Chem. Soc.*, **7**, 481 (1930) [C.A., **24**, 5752 (1930)].

- 4593 Linstead and Williams, *J. Chem. Soc.*, **1926**, 2735.
- 4594 Basu, *J. Indian Chem. Soc.*, **8**, 119 (1931) [*C.A.*, **25**, 4881 (1931)].
- 4595 Friedmann, *J. prakt. Chem.*, [2], **146**, 65 (1936).
- 4596 Mukherji, *Science and Culture India*, **13**, 39 (1947) [*C.A.*, **42**, 2957 (1948)].
- 4597 Profft, Runge, and Jumar, *J. prakt. Chem.*, [4], **1**, 57 (1954).
- 4598 Hill, *J. Am. Chem. Soc.*, **49**, 566 (1927).
- 4599 Vorlaender and Kalkow, *Ber.*, **30**, 2268 (1897).
- 4600 Avery, Biswell, and Liston, *J. Am. Chem. Soc.*, **54**, 229 (1932).
- 4601 Kohler and Rao, *J. Am. Chem. Soc.*, **41**, 1697 (1919).
- 4602 Badger, Cook, and Walker, *J. Chem. Soc.*, **1948**, 2011.
- 4603 Vorlaender and Kunze, *Ber.*, **59**, 2078 (1926).
- 4604 Mehr, Becker, and Spoerri, *J. Am. Chem. Soc.*, **77**, 984 (1955).
- 4605 Wislicenus and Carpenter, *Ann.*, **302**, 223 (1898).
- 4606 Ziegler and Schnell, *Ann.*, **445**, 266 (1925).
- 4607 Michael and Ross, *J. Am. Chem. Soc.*, **54**, 407 (1932); see Michael and Ross, *ibid.*, **52**, 4598 (1930).
- 4608 Allen, Massey, and Nicholls, *J. Am. Chem. Soc.*, **59**, 679 (1937).
- 4609 Kohler, Graustein, and Merrill, *J. Am. Chem. Soc.*, **44**, 2536 (1922).
- 4610 Kohler and Souther, *J. Am. Chem. Soc.*, **44**, 2903 (1922).
- 4611 Rupe and Stern, *Helv. Chim. Acta*, **10**, 859 (1927).
- 4612 Upson, Maxwell, and Parmelee, *J. Am. Chem. Soc.*, **52**, 1971 (1930).
- 4613 Allen and Sallans, *Can. J. Research*, **9**, 574 (1933) [*C.A.*, **28**, 2006 (1934)].
- 4614 Kaplash, Shah, and Wheeler, *J. Indian Chem. Soc.*, **19**, 117 (1942) [*C.A.*, **37**, 375 (1943)].
- 4615 Kaplash, Shah, and Wheeler, *Current Sci. India*, **8**, 512 (1939) [*C.A.*, **34**, 5830 (1940)].
- 4616 Stobbe, *J. prakt. Chem.*, [2], **86**, 209 (1912).
- 4617 Cope, Fawcett, and Munn, *J. Am. Chem. Soc.*, **72**, 3399 (1950).
- 4618 Mikhailov, *J. Gen. Chem. U.S.S.R.*, **7**, 2950 (1937) [*C.A.*, **32**, 5402 (1938)].
- 4619 Kohler, *J. Am. Chem. Soc.*, **46**, 503 (1924).
- 4620 Kohler, *J. Am. Chem. Soc.*, **38**, 889 (1916).
- 4621 Worrall and Bradway, *J. Am. Chem. Soc.*, **58**, 1607 (1936).
- 4622 Dornow and Frese, *Ann.*, **581**, 211 (1953).
- 4623 Tucker and Whalley, *J. Chem. Soc.*, **1949**, 50.
- 4624 Kohler, Hill, and Bigelow, *J. Am. Chem. Soc.*, **39**, 2405 (1917).
- 4625 Kohler and Williams, *J. Am. Chem. Soc.*, **41**, 1644 (1919).
- 4626 Hill, *J. Chem. Soc.*, **1935**, 1115.
- 4627 Kohler and Conant, *J. Am. Chem. Soc.*, **39**, 1699 (1917).
- 4628 Petrow, *Ber.*, **63**, 898 (1930).
- 4629 Diltthey, Trösken, Plum, and Schommer, *J. prakt. Chem.*, [2], **141**, 331 (1934).
- 4630 Petrow and Anzus, *Ber.*, **66**, 420 (1933).
- 4631 Allen and Scarrow, *Can. J. Research*, **11**, 395 (1934) [*C.A.*, **29**, 121 (1935)].
- 4632 Hedenburg and Wachs, *J. Am. Chem. Soc.*, **70**, 2216 (1948).
- 4633 Hedenburg, U.S. pat. 2,524,107 [*C.A.*, **45**, 811 (1951)].
- 4634 Lutz and Palmer, *J. Am. Chem. Soc.*, **57**, 1947 (1935).
- 4635 Garden and Gunstone, *J. Chem. Soc.*, **1952**, 2650.
- 4636 Fuson and Mange, *J. Org. Chem.*, **19**, 806 (1954).
- 4637 Palamvaki, Pissari, and Polimass, *Bull. soc. chim. France*, **1953**, 200.
- 4638 Kwartler and Lindwall, *J. Am. Chem. Soc.*, **59**, 524 (1937).
- 4639 Gostaff and Verheeswater, *Proc. Indian Acad. Sci.*, **15A**, 424 (1942) [*C.A.*, **36**, 7015 (1942)].
- 4640 Lo and Croxall, *J. Am. Chem. Soc.*, **76**, 4166 (1954).
- 4641 Westöö, *Acta Chem. Scand.*, **7**, 355 (1953) [*C.A.*, **48**, 3349 (1954)].
- 4642 Bartlett and Woods, *J. Am. Chem. Soc.*, **62**, 2933 (1940).
- 4643 McCoubrey, *J. Chem. Soc.*, **1951**, 2931.
- 4644 Rosenfelder and Ginsburg, *J. Chem. Soc.*, **1954**, 2955.
- 4645 Colonge, Dreux, and Delplace, *Compt. rend.*, **238**, 1237 (1954).

- ⁶⁴⁶ Colonge, *Bull. soc. chim. France*, **1955**, 250.
⁶⁴⁷ Shaler, Loeb, and Johnson, *J. Am. Chem. Soc.*, **75**, 5963 (1953).
⁶⁴⁸ Rabe, *Ber.*, **37**, 1671 (1904).
⁶⁴⁹ Cronyn and Kesser, *J. Am. Chem. Soc.*, **75**, 1664 (1953).
⁶⁵⁰ Nightingale, Erickson, and Shackelford, *J. Org. Chem.*, **17**, 1005 (1952).
⁶⁵¹ Robinson and Saxton, *J. Chem. Soc.*, **1953**, 2596.
⁶⁵² Basu, *Ann.*, **530**, 131 (1937).
⁶⁵³ Basu, *Ann.*, **514**, 292 (1934).
⁶⁵⁴ Eistert and Reiss, *Chem. Ber.*, **87**, 92 (1954).
⁶⁵⁵ Nazarov and Zav'yulov, *Izvest. Akad. Nauk S.S.S.R. Otdel. Khim. Nauk*, **1952**, 437
C.A., **47**, 5365 (1953)].
⁶⁵⁶ Robinson and Walker, *J. Chem. Soc.*, **1935**, 1530.
⁶⁵⁷ Rabe and Appuhn, *Ber.*, **76**, 982 (1943). Cf. Rabe, *Ann.*, **360**, 1005 (1952).
⁶⁵⁸ Desai, *J. Indian Chem. Soc.*, **10**, 257 (1933) [*C.A.*, **27**, 5310 (1933)].
⁶⁵⁹ Stauffacher and Schinz, *Helv. Chim. Acta*, **37**, 1207 (1954).
⁶⁶⁰ Rosenmund and Herzberg, *Chem. Ber.*, **87**, 1575 (1954).
⁶⁶¹ Eschenmoser, Schreiber, and Julia, *Helv. Chim. Acta*, **36**, 482 (1953).
⁶⁶² Qudrat-I-Khuda and Mukherji, *J. Chem. Soc.*, **1936**, 570.
⁶⁶³ Friedmann and Robinson, *Chemistry & Industry*, **1951**, 777.
⁶⁶⁴ Gunstone and Tulloch, *J. Chem. Soc.*, **1955**, 1130.
⁶⁶⁵ Winternitz, Mousseron, and Rouzier, *Bull. soc. chim. France*, **1954**, 316.
⁶⁶⁶ Amiel, Loeffler, and Ginsburg, *J. Am. Chem. Soc.*, **76**, 3625 (1954).
⁶⁶⁷ Ginsburg, *J. Chem. Soc.*, **1954**, 2361.
⁶⁶⁸ Pappo and Ginsburg, *Bull. Research Council Israel*, **1**, Pt. 1-2, 145 (1951) [*C.A.*, **46**,
7064 (1952)].
⁶⁶⁹ Pappo and Ginsburg, *Bull. Research Council Israel*, **1**, Pt. 3, 121 (1951) [*C.A.*, **47**,
2161 (1953)].
⁶⁷⁰ Sen and Neogi, *J. Indian Chem. Soc.*, **7**, 305 (1930) [*C.A.*, **24**, 4767 (1930)].
⁶⁷¹ McQuillin, *Chemistry & Industry*, **1954**, 311.
⁶⁷² Dutta, Chakravarti, and Dutta, *Chemistry & Industry*, **1955**, 170.
⁶⁷³ Mukharji and Raha, *Science and Culture India*, **19**, 569 (1954) [*C.A.*, **49**, 5414 (1955)].
⁶⁷⁴ Birch and Quartey, *Chemistry & Industry*, **1953**, 489.
⁶⁷⁵ Ott and Tarbell, *J. Am. Chem. Soc.*, **74**, 6266 (1952).
⁶⁷⁶ Ginsburg, *J. Am. Chem. Soc.*, **76**, 3628 (1954).
⁶⁷⁷ Parihar and Dutt, *Indian Soap J.*, **16**, 154 (1950) [*C.A.*, **46**, 8066 (1952)].
⁶⁷⁸ Ralls, *J. Am. Chem. Soc.*, **75**, 2123 (1953).
⁶⁷⁹ Mannich and Fournau, *Ber.*, **71**, 2090 (1938).
⁶⁸⁰ Bardhan, *Chemistry & Industry*, **1940**, 369.
⁶⁸¹ Cardwell and McQuillin, *J. Chem. Soc.*, **1949**, 708.
⁶⁸² Jacquier and Boyer, *Bull. soc. chim. France*, **1955**, 8.
⁶⁸³ Jacquier and Boyer, *Bull. soc. chim. France*, **1954**, 717.
⁶⁸⁴ Roy, *Science and Culture India*, **19**, 156 (1953) [*C.A.*, **48**, 13660 (1954)].
⁶⁸⁵ Martin and Robinson, *J. Chem. Soc.*, **1949**, 1866.
⁶⁸⁶ Robinson and Seijo, *J. Chem. Soc.*, **1941**, 582.
⁶⁸⁷ Hussey, Liao, and Baker, *J. Am. Chem. Soc.*, **75**, 4727 (1953).
⁶⁸⁸ Prelog, Wirth, and Ruzicka, *Helv. Chim. Acta*, **29**, 1425 (1946).
⁶⁸⁹ Prelog, Barman, and Zimmermann, *Helv. Chim. Acta*, **32**, 1284 (1949).
⁶⁹⁰ Prelog, Ruzicka, Barman, and Frenkiel, *Helv. Chim. Acta*, **31**, 92 (1948).
⁶⁹¹ Gill, James, Lions, and Potts, *J. Am. Chem. Soc.*, **74**, 4923 (1952).
⁶⁹² Wilds, Hoffman, and Pearson, *J. Am. Chem. Soc.*, **77**, 647 (1955).
⁶⁹³ Johnston and Holly, U.S. pat. 2,671,808 [*C.A.*, **49**, 3264 (1955)].
⁶⁹⁴ Banerjee, Chatterjee, and Bhattacharya, *J. Am. Chem. Soc.*, **77**, 408 (1955).
⁶⁹⁵ Buechi, Jeger, and Ruzicka, *Helv. Chim. Acta*, **31**, 241 (1948).
⁶⁹⁶ Robinson and Weygand, *J. Chem. Soc.*, **1941**, 386.
⁶⁹⁷ Cook and Robinson, *J. Chem. Soc.*, **1941**, 391.
⁶⁹⁸ Cornforth and Robinson, *J. Chem. Soc.*, **1946**, 676.

- 699 Grob and Jundt, *Helv. Chim. Acta*, **31**, 1691 (1948).
- 700 Shunk and Wilds, *J. Am. Chem. Soc.*, **71**, 3946 (1949).
- 701 Ghosh and Robinson, *J. Chem. Soc.*, **1944**, 506.
- 702 Wilds and Shunk, *J. Am. Chem. Soc.*, **72**, 2388 (1950).
- 703 Martin and Robinson, *J. Chem. Soc.*, **1943**, 491.
- 704 Mukharji, *J. Indian Chem. Soc.*, **24**, 91 (1947) [*C.A.*, **42**, 1312 (1948)].
- 705 Huang, *J. Chem. Soc.*, **1954**, 3655.
- 706 Wieland and Miescher, *Helv. Chim. Acta*, **33**, 2215 (1950).
- 707 CIBA, Swiss pat. 293,104 [*C.A.*, **49**, 3263 (1955)].
- 708 Chaudhary and Mukharji, *Science and Culture India*, **18**, 602 (1953) [*C.A.*, **48**, 7592 (1954)].
- 709 Wendler, Slaters, and Tishler, *J. Am. Chem. Soc.*, **73**, 3816 (1951).
- 710 Reichert and Posemann, *Arch. Pharm.*, **275**, 67 (1937) [*C.A.*, **31**, 3984 (1937)].
- 711 Barltrop, *J. Chem. Soc.*, **1946**, 958.
- 712 Cardwell, *J. Chem. Soc.*, **1949**, 715.
- 713 Szmuszkowicz and Born, *J. Am. Chem. Soc.*, **75**, 3350 (1953).
- 714 McQuillin, *J. Chem. Soc.*, **1955**, 528.
- 715 Roy, *Chemistry & Industry*, **1954**, 1393.
- 716 Howe and McQuillin, *J. Chem. Soc.*, **1955**, 2423.
- 717 Adamson, McQuillin, Robinson, and Simonsen, *J. Chem. Soc.*, **1937**, 1576.
- 718 Abe, Harukawa, Ishikawa, Miki, Sumi, and Toga, *J. Am. Chem. Soc.*, **75**, 2567 (1953).
- 719 Abe, Harukawa, Ishikawa, Miki, Sumi, and Toga, *Proc. Japan Acad.*, **29**, 113 (1953) [*C.A.*, **48**, 10706 (1954)].
- 720 Roy, *Science and Culture India*, **19**, 266 (1953) [*C.A.*, **49**, 1676 (1955)].
- 721 Szmuszkowicz, *J. Org. Chem.*, **19**, 1424 (1954).
- 722 Jacquier and Boyer, *Bull. soc. chim. France*, **1954**, 442.
- 723 Mannich and Koch, *Ber.*, **75**, 803 (1942).
- 724 Mannich, Koch, and Borkowsky, *Ber.*, **70**, 355 (1937).
- 725 Logan, Marvell, La Pore, and D. C. Bush, *J. Am. Chem. Soc.*, **76**, 4127 (1954).
- 726 Jacquier and Lanet, *Bull. soc. chim. France*, **1953**, 795.
- 727 Treibs and Muehlstaedt, *Chem. Ber.*, **87**, 407 (1954).
- 728 Jacquier and Christol, *Bull. soc. chim. France*, **1954**, 556.
- 729 Novello, Christy, and Sprague, *J. Am. Chem. Soc.*, **75**, 1330 (1953).
- 730 F. C. Novello, private communication.
- 731 Cope and Hermann, *J. Am. Chem. Soc.*, **72**, 3405 (1950).
- 732 Harradence and Lions, *J. Proc. Roy. Soc. N.S. Wales*, **72**, 284 (1939) [*C.A.*, **33**, 6825 (1939)].
- 733 Gill and Lions, *J. Am. Chem. Soc.*, **72**, 3468 (1950).
- 734 Juday, *J. Am. Chem. Soc.*, **75**, 4071 (1953).
- 735 Novello and Christy, *J. Am. Chem. Soc.*, **75**, 5431 (1953).
- 736 Lieberman and Wagner, *J. Org. Chem.*, **14**, 1001 (1949).
- 737 Dalgliesh, *J. Am. Chem. Soc.*, **71**, 1697 (1949).
- 738 Eliel, *J. Am. Chem. Soc.*, **73**, 43 (1951).
- 739 Snyder and Hamlin, *J. Am. Chem. Soc.*, **72**, 5082 (1950).
- 740 Bernatek, *Acta Chem. Scand.*, **7**, 677 (1953) [*C.A.*, **48**, 4501 (1954)].
- 741 Ionescu, *Bull. soc. chim. France*, [4], **41**, 1094 (1927).
- 742 Smith and Nichols, *J. Am. Chem. Soc.*, **65**, 1739 (1943).
- 743 Smith and Wiley, *J. Am. Chem. Soc.*, **68**, 894 (1946).
- 744 Smith and Byers, *J. Am. Chem. Soc.*, **63**, 612 (1941).
- 745 Smith and MacMullen, *J. Am. Chem. Soc.*, **58**, 629 (1936).
- 746 Bergel, Jacob, Todd, and Work, *J. Chem. Soc.*, **1938**, 1375.
- 747 Smith and Johnson, *J. Am. Chem. Soc.*, **59**, 673 (1937).
- 748 Smith, *J. Am. Chem. Soc.*, **56**, 472 (1934).
- 749 Smith and Denyes, *J. Am. Chem. Soc.*, **58**, 304 (1936).
- 750 Smith and Opie, *J. Am. Chem. Soc.*, **63**, 932 (1941).
- 751 Smith and Webster, *J. Am. Chem. Soc.*, **59**, 662 (1937).

- ^{749a} Adams and Acker, *J. Am. Chem. Soc.* **74**, 5872 (1952).
- ⁷⁵⁰ Adams and Blomstrom, *J. Am. Chem. Soc.*, **75**, 3404 (1953).
- ⁷⁵¹ Adams and Moje, *J. Am. Chem. Soc.*, **74**, 5557 (1952).
- ⁷⁵² Adams and Way, *J. Am. Chem. Soc.*, **76**, 2763 (1954).
- ⁷⁵³ CIBA, Swiss pat. 276,141 [*C.A.*, **47**, 7546 (1953)].
- ⁷⁵⁴ CIBA, British pat. 666,713 [*C.A.*, **47**, 7546 (1953)].
- ⁷⁵⁵ Hoffmann and Tagmann, *Helv. Chim. Acta*, **32**, 1470 (1949).
- ⁷⁵⁶ E. I. du Pont de Nemours and Co., Brit. pat. 576,427 [*C.A.*, **42**, 2269 (1948)].
- ⁷⁵⁷ Hoch and Karrer, *Helv. Chim. Acta*, **37**, 397 (1954).
- ⁷⁵⁸ Fuson and Miller, *J. Org. Chem.*, **17**, 886 (1952).
- ⁷⁵⁹ Terent'ev and Gurvich, *Vestnik Moskov. Univ.*, **5**, No. 5 (1950) [*C.A.*, **45**, 7005 (1951)].
- ⁷⁶⁰ Bruson, U.S. pat. 2,383,444 [*C.A.*, **40**, 351 (1946)].
- ⁷⁶¹ Bruson and Riener, *J. Am. Chem. Soc.*, **64**, 2850 (1942).
- ⁷⁶² Baumgarten and Eifert, *J. Am. Chem. Soc.*, **75**, 3015 (1953).
- ⁷⁶³ Wiest and Glaser, U.S. pat. 2,403,570 [*C.A.*, **40**, 6498 (1946)].
- ⁷⁶⁴ Frank and McPherson, Jr., *J. Am. Chem. Soc.*, **71**, 1387 (1949).
- ⁷⁶⁵ Bruson, U.S. pat. 2,386,736 [*C.A.*, **40**, 7234 (1946)].
- ⁷⁶⁶ Terent'ev and Gurvich, *Sbornik Statei Obshchei Khim. Akad. Nauk S.S.S.R.*, **1**, 404 (1953) [*C.A.*, **49**, 1047 (1955)].
- ⁷⁶⁷ Terent'ev, Kost, and Gurvich, *Zhur. Obshchei Khim.*, **22**, 1977 (1952) [*C.A.*, **47**, 8663 (1953)].
- ⁷⁶⁸ Levina, Shusherina, and Kaminskaya, *Doklady Akad. Nauk S.S.S.R.*, **86**, 79 (1952) [*C.A.*, **47**, 4849 (1953)].
- ⁷⁶⁹ Nazarov, Shvekgheimer, and Rudenko, *Zhur. Obshchei Khim.*, **24**, 319 (1954) [*C.A.*, **49**, 4651 (1955)].
- ⁷⁷⁰ Nazarov and Zav'yalov, *Zhur. Obshchei Khim.*, **24**, 469 (1954) [*C.A.*, **49**, 6142 (1955)].
- ⁷⁷¹ Stetter and Coenen, *Chem. Ber.*, **87**, 990 (1954).
- ⁷⁷² Iwanoff, *Chem. Ber.*, **87**, 1600 (1954).
- ⁷⁷³ Boekelheide, *J. Am. Chem. Soc.*, **69**, 790 (1947).
- ⁷⁷⁴ Barkley, Farrar, Knowles, Raffelson, and Thompson, *J. Am. Chem. Soc.*, **76**, 5014 (1954).
- ⁷⁷⁵ Pinder and Robinson, *Nature*, **167**, 484 (1951).
- ⁷⁷⁶ Chem. Werke Huels, Ger. pat. 811,350 [*C.A.*, **47**, 3337 (1953)].
- ⁷⁷⁷ Daub and Doyle, *J. Am. Chem. Soc.*, **74**, 4449 (1952).
- ⁷⁷⁸ Acara and Levine, *J. Am. Chem. Soc.*, **72**, 2864 (1950).
- ⁷⁷⁹ Horning and Rutenberg, *J. Am. Chem. Soc.*, **72**, 3534 (1950).
- ⁷⁸⁰ Albertson and Fillman, *J. Am. Chem. Soc.*, **71**, 2818 (1949).
- ⁷⁸¹ Mikeska, U.S. pat. 2,461,336 [*C.A.*, **43**, 4689 (1949)].
- ^{781a} Hesse and Buecking, *Ann.*, **563**, 31 (1949).
- ⁷⁸² Smrt and Šorm, *Collections Czechoslov. Chem. Commun.*, **18**, 131 (1953) [*C.A.*, **48**, 3903 (1954)].
- ⁷⁸³ Ansell and Hey, *J. Chem. Soc.*, **1950**, 1683.
- ⁷⁸⁴ Floyd, *J. Am. Chem. Soc.*, **71**, 1746 (1949).
- ⁷⁸⁵ Wideqvist, *Arkiv Kemi*, **3**, 59 (1951) [*C.A.*, **45**, 10217 (1951)].
- ⁷⁸⁶ Green and Hey, *J. Chem. Soc.*, **1954**, 4306.
- ⁷⁸⁷ Newman and McPherson, *J. Org. Chem.*, **19**, 1717 (1954).
- ⁷⁸⁸ Talukdar and Bagchi, *Science and Culture India*, **19**, 201 (1953) [*C.A.*, **49**, 1656 (1955)].
- ⁷⁸⁹ Talukdar and Bagchi, *J. Org. Chem.*, **20**, 21 (1955).
- ⁷⁹⁰ Talukdar and Bagchi, *Science and Culture India*, **18**, 503 (1953) [*C.A.*, **48**, 8180 (1954)].
- ⁷⁹¹ Raha and Mukharji, *J. Org. Chem.*, **19**, 1376 (1954).
- ⁷⁹² Horning and Finelli, *J. Am. Chem. Soc.*, **71**, 3204 (1949), *Org. Syntheses*, **30**, 80 (1950).
- ⁷⁹³ Banerjee and Shafer, *J. Am. Chem. Soc.*, **72**, 1931 (1950).
- ⁷⁹⁴ Walter and Barry, U.S. pat. 2,524,643 [*C.A.*, **45**, 7154 (1951)].
- ⁷⁹⁵ Campbell and Tucker, *J. Chem. Soc.*, **1949**, 2623.
- ⁷⁹⁶ Holbro and Tagmann, *Helv. Chim. Acta*, **33**, 2178 (1950).
- ⁷⁹⁷ Campbell and Reid, *J. Chem. Soc.*, **1952**, 3281.

- 798 Boekelheide, Linn, O'Grady, and Lamborg, *J. Am. Chem. Soc.*, **75**, 3243 (1953).
- 799 Yoho and Levine, *J. Am. Chem. Soc.*, **74**, 5597 (1952).
- 800 Misra and Shukla, *J. Indian Chem. Soc.*, **29**, 455 (1952).
- 801 Misra and Shukla, *J. Indian Chem. Soc.*, **30**, 37 (1953).
- 802 Koelsch and Walker, *J. Am. Chem. Soc.*, **72**, 346 (1950).
- 803 Nakazawa and Matsuura, *J. Pharm. Soc. Japan*, **72**, 51 (1952) [*C.A.*, **46**, 11142 (1952)].
- 804 Bachmann and Johnson, *J. Am. Chem. Soc.*, **71**, 3463 (1949).
- 805 Kost and Terent'ev, *J. Gen. Chem. U.S.S.R.*, **22**, 655 (1952) [*C.A.*, **47**, 2759 (1953)].
- 806 Boekelheide and Godfrey, *J. Am. Chem. Soc.*, **75**, 3679 (1953).
- 807 Misra and Shukla, *J. Indian Chem. Soc.*, **29**, 201 (1952).
- 808 Rubin and Wishinsky, *J. Am. Chem. Soc.*, **68**, 828 (1946).
- 809 Tagmann, Sury, and Hoffmann, *Helv. Chim. Acta*, **35**, 1541 (1952).
- 810 Herzog, Gold, and Geckler, *J. Am. Chem. Soc.*, **73**, 749 (1951).
- 811 Klager, *J. Org. Chem.*, **16**, 161 (1951).
- 812 Boyd and Leshin, *J. Am. Chem. Soc.*, **74**, 2675 (1952).
- 813 Rodionov and Belikov, *Doklady Akad. Nauk S.S.S.R.*, **93**, 827 (1953) [*C.A.*, **49**, 1550 (1955)].
- 814 Klager, *J. Org. Chem.*, **20**, 650 (1955).
- 815 Bruson, U.S. pat. 2,435,552 [*C.A.*, **42**, 3778 (1948)].
- 816 Asthana and Misra, *J. Indian Chem. Soc.*, **31**, 459 (1954).
- 817 Ladd, U.S. pat. 2,632,019 [*C.A.*, **48**, 1418 (1954)].
- 818 Fiszer and Michalski, *Roczniki Chem.*, **28**, 185 (1954) [*C.A.*, **49**, 9493 (1955)].
- 819 Koelsch, *J. Am. Chem. Soc.*, **65**, 2460 (1943).
- 820 Koelsch, *J. Am. Chem. Soc.*, **68**, 146 (1946).
- 821 Koelsch and Rolfson, *J. Am. Chem. Soc.*, **72**, 1871 (1950).
- 822 Birch and Kon, *J. Chem. Soc.*, **123**, 2440 (1923).
- 823 Linstead and Millidge, *J. Chem. Soc.*, **1936**, 478.
- 824 Oesterr. Stickstoffwerke A.G., Austrian pat. 176,845 [*C.A.*, **48**, 10772 (1954)].
- 825 Albertson, *J. Am. Chem. Soc.*, **70**, 669 (1948).
- 826 Koelsch, *J. Am. Chem. Soc.*, **65**, 2458 (1943).
- 827 Sury and Hoffmann, *Helv. Chim. Acta*, **36**, 1815 (1953); cf. Tagmann, Sury, and Hoffmann, *Helv. Chim. Acta*, **35**, 1235, 1541 (1952).
- 828 Johnson, Johnson, and Petersen, *J. Am. Chem. Soc.*, **68**, 1926 (1946).
- 829 Schneider, Riener, and Bruson, *J. Am. Chem. Soc.*, **72**, 1486 (1950).
- 830 Lloyd and Horning, *J. Am. Chem. Soc.*, **76**, 3651 (1954).
- 831 Bruson, U.S. pat. 2,390,918 [*C.A.*, **40**, 2456 (1946)].
- 832 Micheel and Albers, *Ann.*, **581**, 225 (1953).
- 833 Kloetzel, *J. Am. Chem. Soc.*, **70**, 3571 (1948).
- 834 Theilacker and Wendtland, *Ann.*, **570**, 33 (1950).
- 835 Moffett, *Org. Syntheses*, **32**, 86 (1952).
- 836 Brown and van Gulick, *J. Am. Chem. Soc.*, **77**, 1079 (1955).
- 837 Klager, U.S. pat. 2,640,072 [*C.A.*, **48**, 7626 (1954)].
- 838 Klager, U.S. pat. 2,668,176 [*C.A.*, **49**, 4013 (1955)].
- 839 Floyd and Miller, *J. Org. Chem.*, **16**, 882 (1951).
- 840 Kappeler, Stauffacher, Eschenmoser, and Schinz, *Helv. Chim. Acta*, **37**, 957 (1954).
- 841 Stauffacher and Schinz, *Helv. Chim. Acta*, **37**, 1223 (1954).
- 842 Perkin, Jr., and Thorpe, *J. Chem. Soc.*, **85**, 128 (1904).
- 843 Perkin, Perkin, Meier, and Keller, *Helv. Chim. Acta*, **37**, 266 (1954).
- 844 Barat, *J. Indian Chem. Soc.*, **8**, 37 (1931).
- 845 Stetter, Buentgen, and Coenen, *Chem. Ber.*, **88**, 77 (1955).
- 846 Horner, *Ann.*, **548**, 117 (1941).
- 847 Palazzo and Rosnati, *Gazz. chim. ital.*, **82**, 584 (1952).
- 848 Weisblat and Lyttle, U.S. pat. 2,606,921 [*C.A.*, **47**, 4903 (1953)].
- 849 Dryamova, Zav'yalov, and Prusil'nykh, *J. Gen. Chem. U.S.S.R.*, **18**, 1733 (1948) [*C.A.*, **43**, 2625 (1949)].
- 850 Woods, *J. Am. Chem. Soc.*, **75**, 1510 (1953).

- 850 Hunsdiecker, *Ber.*, **75**, 1197 (1942).
- 851 Komppa and Rohrmann, *Ann. Acad. Sci. Fennicae*, **A44**, No. 3 (1935) [*C.A.*, **30**, 2949 (1936)].
- 852 Scheibler, Emden, and Neubner, *Ber.*, **63**, 1557 (1930).
- 853 Edwards, Jr., and Cashaw, *J. Am. Chem. Soc.*, **76**, 6188 (1954).
- 854 Schilling and Vorlaender, *Ann.*, **308**, 184 (1899).
- 855 Blanchard and Goering, *J. Am. Chem. Soc.*, **73**, 5863 (1951).
- 856 Bhattacharyya, *J. Indian Chem. Soc.*, **22**, 214 (1945).
- 857 Bhattacharyya, *Science and Culture India*, **8**, 426 (1943) [*C.A.*, **37**, 5031 (1943)].
- 858 Herz, *J. Org. Chem.*, **20**, 1062 (1955).
- 859 Chakravarti, *J. Indian Chem. Soc.*, **21**, 319 (1944).
- 860 Hope and Perkin, Jr., *J. Chem. Soc.*, **99**, 762 (1911).
- 861 Barltrop, *J. Chem. Soc.*, **1947**, 399.
- 862 Ruhemann and Wolf, *J. Chem. Soc.*, **69**, 1383 (1896).
- 863 Cook, Pierce, and McBee, *J. Am. Chem. Soc.*, **76**, 83 (1954).
- 864 Noller and Pannell, *J. Am. Chem. Soc.*, **77**, 1862 (1955).
- 865 Talukdar and Bagchi, *J. Org. Chem.*, **20**, 25 (1955).
- 866 von Auwers and Koebner, *Ber.*, **24**, 1935 (1891).
- 867 Ruzicka, *Helv. Chim. Acta*, **2**, 144 (1919).
- 868 Phalnikar and Nargund, *J. Univ. Bombay*, **4**, 106 (1935) [*C.A.*, **30**, 5186 (1936)].
- 869 Miwa, Ohsuka, and Sakan, *J. Chem. Soc. Japan Pure Chem. Sect.*, **74**, 113 (1953) [*C.A.*, **48**, 9962 (1954)].
- 870 Welch, *J. Chem. Soc.*, **1930**, 257.
- 871 Kotake, Sakan, and Miwa, *J. Am. Chem. Soc.*, **72**, 5085 (1950).
- 872 Romeo, Corrodi, and Hardegger, *Helv. Chim. Acta*, **38**, 463 (1955).
- 873 Phalnikar, *J. Univ. Bombay*, **19**, Sect. A, Pt. 3, Ser. No. 28, 62 (1950) [*C.A.*, **47**, 1606 (1953)].
- 874 Aoki, *J. Pharm. Soc. Japan*, **66**, 51 (1946) [*C.A.*, **45**, 6173 (1951)].
- 875 Ruhemann and Browning, *J. Chem. Soc.*, **73**, 727 (1898).
- 876 Ghosh, *J. Indian Chem. Soc.*, **24**, 45 (1947).
- 877 Staudinger, *Ann.*, **341**, 99 (1905).
- 878 Ruhemann and Cunningham, *J. Chem. Soc.*, **73**, 1006 (1898).
- 879 Challenger and Fishwick, *J. Inst. Petroleum*, **39**, 220 (1953) [*C.A.*, **48**, 9355 (1954)].
- 880 Malachowski, Bilbel, and Biliński-Tarasowicz, *Ber.*, **69**, 1295 (1936).
- 881 Henze, *Ber.*, **33**, 966 (1900).
- 882 Ruhemann, *J. Chem. Soc.*, **71**, 325 (1897).
- 883 Ruhemann and Stapleton, *J. Chem. Soc.*, **77**, 804 (1900).
- 884 Ruhemann and Tyler, *J. Chem. Soc.*, **69**, 530 (1896).
- 885 Woodward and Read, *J. Am. Chem. Soc.*, **65**, 1569 (1943).
- 886 Perkin, Jr., *J. Chem. Soc.*, **69**, 1472 (1896).
- 887 Ray, *J. Am. Chem. Soc.*, **50**, 558 (1928).
- 888 Blaise, *Compt. rend.*, **136**, 243 (1903).
- 889 Blaise and Luttringer, *Bull. soc. chim. France*, [3], **33**, 760 (1905).
- 890 Kohler and Reid, *J. Am. Chem. Soc.*, **47**, 2803 (1925).
- 891 Leonard and Shoemaker, *J. Am. Chem. Soc.*, **71**, 1876 (1949).
- 892 Komnenos, *Ann.*, **218**, 145 (1883).
- 893 Koetz and Stalman, *J. prakt. Chem.*, [2], **68**, 156 (1903).
- 894 Knoevenagel, *Ber.*, **31**, 2585 (1898).
- 895 Gupta, *J. Chem. Soc.*, **119**, 298 (1921).
- 896 Day and Thorpe, *J. Chem. Soc.*, **117**, 1469 (1920).
- 897 Diels, Gaertner, and Kaack, *Ber.*, **55**, 3439 (1922).
- 898 Sonn, *Ber.*, **61**, 2479 (1928).
- 899 Robinson and Thompson, *J. Chem. Soc.*, **1938**, 2009.
- 900 Farmer, *J. Chem. Soc.*, **123**, 3324 (1923).
- 901 Koetz, *J. prakt. Chem.*, [2], **75**, 433 (1907).
- 902 Gaiind and Guha, *J. Indian Chem. Soc.*, **11**, 421 (1934).

- ⁹⁰³ Clemo and Welch, *J. Chem. Soc.*, **1928**, 2621.
- ⁹⁰⁴ Kerr, *J. Am. Chem. Soc.*, **51**, 614 (1929).
- ⁹⁰⁵ Mayimadathan and Guha, *J. Indian Inst. Sci.*, **15A**, 131 (1932) [*C.A.*, **27**, 3211 (1933)].
- ⁹⁰⁶ Komppa, *Ber.*, **33**, 3530 (1900).
- ⁹⁰⁷ Brown and van Gulick, *J. Am. Chem. Soc.*, **77**, 1083 (1955).
- ⁹⁰⁸ Zakharskii and Preobrazhenskii, *Zhur. Obshchei Khim.*, **22**, 1890 (1952) [*C.A.*, **47**, 7507 (1953)].
- ⁹⁰⁹ Bainova, Evstigneeva, Livshits, Kuz'mina, and Preobrazhenskii, *Zhur. Obshchei Khim.*, **23**, 149 (1953) [*C.A.*, **48**, 1360 (1954)].
- ⁹¹⁰ Curtis, Day, and Kimmins, *J. Chem. Soc.*, **123**, 3131 (1923).
- ⁹¹¹ Ingold and Shoppee, *J. Chem. Soc.*, **1926**, 1912.
- ⁹¹² Ingold, Shoppee, and Thorpe, *J. Chem. Soc.*, **1926**, 1477.
- ⁹¹³ Arnold, Amidon, and Dodson, *J. Am. Chem. Soc.*, **72**, 2871 (1950).
- ⁹¹⁴ Bertram, *Ber.*, **36**, 3291 (1903).
- ⁹¹⁵ Ranganathan, *Current Sci. India*, **9**, 276 (1940) [*C.A.*, **34**, 7861 (1940)].
- ⁹¹⁶ Ingold and Perren, *J. Chem. Soc.*, **119**, 1582 (1921).
- ^{916a} Henrich, *Ber.*, **35**, 1663 (1902).
- ⁹¹⁷ Knoevenagel, Ger. pat. 156,560 [*Chem. Zentr.*, **1905**, **I**, 56].
- ⁹¹⁸ Ruhemann and Cunnington, *J. Chem. Soc.*, **75**, 778 (1899).
- ⁹¹⁹ Traube, *Ber.*, **40**, 4942 (1907).
- ⁹²⁰ Malachowski and Czornodola, *Ber.*, **68**, 363 (1935).
- ⁹²¹ Ingold and Perren, *J. Chem. Soc.*, **121**, 1414 (1922).
- ⁹²² Claisen, *Ann.*, **297**, 1 (1897), especially p. 88.
- ⁹²³ Boekelheide and Lodge, Jr., *J. Am. Chem. Soc.*, **73**, 3681 (1951).
- ⁹²⁴ Boekelheide and Gall, *J. Org. Chem.*, **19**, 499 (1954).
- ⁹²⁵ Kohler and Butler, *J. Am. Chem. Soc.*, **48**, 1036 (1926).
- ⁹²⁶ Farmer and Healey, *J. Chem. Soc.*, **1927**, 1065.
- ⁹²⁷ Farmer and Mehta, *J. Chem. Soc.*, **1930**, 1610.
- ⁹²⁸ Vorlaender, Weissheimer, and Sponnagel, *Ann.*, **345**, 227 (1906).
- ⁹²⁹ Cairns, Engelhardt, Jackson, Kalb, and Sauer, *J. Am. Chem. Soc.*, **74**, 5636 (1952).
- ⁹³⁰ Farmer and Martin, *J. Chem. Soc.*, **1933**, 960.
- ⁹³¹ Blood, Cartwright, and Linstead, *J. Chem. Soc.*, **1952**, 2268.
- ⁹³² Farmer and Mehta, *J. Chem. Soc.*, **1931**, 1762.
- ⁹³³ Campbell and Rydon, *J. Chem. Soc.*, **1953**, 3002.
- ⁹³⁴ Bardhan and Banerji, *J. Chem. Soc.*, **1935**, 474.
- ⁹³⁵ Sircar, *J. Chem. Soc.*, **1927**, 1252.
- ⁹³⁶ Kon and Nanji, *J. Chem. Soc.*, **1932**, 2426.
- ⁹³⁷ Prelog and Metzler, *Helv. Chim. Acta*, **29**, 1170 (1946).
- ⁹³⁸ Helfer, *Helv. Chim. Acta*, **9**, 814 (1926).
- ⁹³⁹ Bhattacharyya, *J. Indian Chem. Soc.*, **22**, 85 (1945).
- ⁹⁴⁰ Chatterjee, *J. Indian Chem. Soc.*, **14**, 417 (1937).
- ⁹⁴¹ Sen and Bose, *J. Indian Chem. Soc.*, **4**, 51 (1927).
- ⁹⁴² Bardhan and Banerji, *J. Chem. Soc.*, **1935**, 476.
- ⁹⁴³ Vogel, *J. Chem. Soc.*, **1931**, 907.
- ⁹⁴⁴ Rao, *J. Chem. Soc.*, **1929**, 1954.
- ⁹⁴⁵ Reichstein, Zschokke, Gehring, and Rona, *Helv. Chim. Acta*, **15**, 1118 (1932).
- ⁹⁴⁶ Gilmour and Mikhlin, *Doklady Akad. Nauk S.S.S.R.*, **88**, 1003 (1953) [*C.A.*, **48**, 8782 (1954)].
- ⁹⁴⁷ Herrmann and Vorlaender, *Abhandl. naturforsch. Ges. Halle*, **21**, 251 (1899).
- ⁹⁴⁸ Stobbe, *Ann.*, **315**, 219 (1901).
- ⁹⁴⁹ Desai, *J. Chem. Soc.*, **1932**, 1079.
- ⁹⁵⁰ Barr and Cook, *J. Chem. Soc.*, **1945**, 438.
- ⁹⁵¹ Erlenmeyer, Jr., *Ber.*, **33**, 2006 (1900).
- ⁹⁵² Helmkamp, Tanghe, and Plati, *J. Am. Chem. Soc.*, **62**, 3215 (1940).
- ⁹⁵³ Stobbe, *Ber.*, **34**, 653 (1901).
- ⁹⁵⁴ Lawson, Perkin, Jr., and Robinson, *J. Chem. Soc.*, **125**, 626 (1924).

- 953 Chase and Walker, *J. Chem. Soc.*, **1953**, 3548.
- 956 Vorlaender and Strunck, *Ann.*, **345**, 233 (1906).
- 957 Meerwein and co-workers, *J. prakt. Chem.*, [2], **116**, 229 (1927).
- 958 Vachon, Gagnon, and Kane, *Can. J. Research*, **11**, 644 (1934) [*C.A.*, **29**, 1987 (1935)].
- 959 Kohler and Darling, *J. Am. Chem. Soc.*, **52**, 1174 (1930).
- 960 Gravel, *Naturaliste can.*, **57**, 181 (1931) [*C.A.*, **28**, 169 (1934)].
- 961 Bredt, *Ber.*, **24**, 603 (1891).
- 962 Knoevenagel and Fries, *Ber.*, **31**, 761 (1898).
- 963 Knoevenagel and Brunswig, *Ber.*, **35**, 2177 (1902).
- 964 Kroeker and McElvain, *J. Am. Chem. Soc.*, **56**, 1171 (1934).
- 965 Kohler and Barrett, *J. Am. Chem. Soc.*, **48**, 1773 (1926).
- 966 Kohler and Darling, *J. Am. Chem. Soc.*, **52**, 424 (1930).
- 967 Papadakis, *J. Am. Chem. Soc.*, **67**, 1799 (1945).
- 968 Papadakis, Serghano, Chin, and Adrian, *J. Am. Chem. Soc.*, **72**, 4256 (1950).
- 969 Palit, *J. Indian Chem. Soc.*, **14**, 219 (1937).
- 970 Rabe, *Ber.*, **31**, 1896 (1898).
- 971 Meerwein, *Ann.*, **360**, 323 (1908).
- 972 Newman and Joshel, *J. Am. Chem. Soc.*, **60**, 485 (1938).
- 973 Koelsch, U.S. pat. 2,507,473 [*C.A.*, **44**, 7883 (1950)].
- 974 Koelsch, *J. Am. Chem. Soc.*, **67**, 569 (1945).
- 975 Emery, *J. prakt. Chem.*, [2], **53**, 308 (1896).
- 976 Henecka, *Chem. Ber.*, **82**, 36 (1949).
- 977 Isler, Gutmann, Straub, Fust, Bohm, and Studer, *Helv. Chim. Acta*, **38**, 1933 (1955).
- 978 Mumm and Hueneke, *Ber.*, **50**, 1568 (1917).
- 979 Mumm and Hueneke, *Ber.*, **51**, 150 (1918).
- 980 Tracy and Elderfield, *J. Org. Chem.*, **6**, 70 (1941).
- 981 Horning, Denekas, and Field, *J. Org. Chem.*, **9**, 547 (1944).
- 982 Rabe and Elze, *Ann.*, **323**, 83 (1902).
- 983 West, *J. Biol. Chem.*, **66**, 63 (1925).
- 984 Pastour, *Compt. rend.*, **237**, 1094 (1953).
- 985 Gruber and Schloegl, *Monatsh.*, **81**, 83 (1950).
- 986 Nazarov and Zav'yalov, *Izvest. Akad. Nauk S.S.S.R. Otdel. Khim. Nauk*, **1952**, 703 [*C.A.*, **47**, 10515 (1953)].
- 986a Wallach, *Ann.*, **323**, 135 (1902).
- 987 Merling, *Ber.*, **38**, 979 (1905).
- 988 Merling and Welde, *Ann.*, **366**, 119 (1909).
- 989 Jeger and Buechi, *Helv. Chim. Acta*, **31**, 134 (1948).
- 990 Knoevenagel, *Ann.*, **288**, 323 (1895).
- 991 Mukherji, *Science and Culture India*, **8**, 190 (1942) [*C.A.*, **37**, 1994 (1943)].
- 992 Knoevenagel, *Ann.*, **281**, 25 (1894).
- 993 Cornuier, Bittel, de Deme, Gerner, Humeau, Le Bihan, and Sarkis, *Bull. Acad. Sci. France*, [5], **2**, 195 (1935).
- 994 Knoevenagel, *Ann.*, **303**, 223 (1898).
- 995 Schilling and Vorlaender, *Ann.*, **308**, 184 (1899).
- 996 Dyer, Kidd, and Walker, *J. Chem. Soc.*, **1952**, 4778.
- 997 Knoevenagel, *J. prakt. Chem.*, [2], **97**, 288 (1918).
- 998 Bachmann, Fujimoto, and Raunio, *J. Am. Chem. Soc.*, **72**, 2533 (1950).
- 999 Simonsen, *J. Chem. Soc.*, **97**, 1910 (1910).
- 1000 Urech, Tagmann, Sury, and Hoffmann, *Helv. Chim. Acta*, **36**, 1809 (1953).
- 1001 Feist, *Ann.*, **345**, 100 (1906).
- 1002 Feist, *Ann.*, **345**, 60 (1906).
- 1003 Milas, U.S. pat. 2,369,158 [*C.A.*, **39**, 5044 (1945)].
- 1004 Milas, U.S. pat. 2,432,921 [*C.A.*, **42**, 2278 (1948)].
- 1005 Thorpe and Wood, *J. Chem. Soc.*, **103**, 1569 (1913).
- 1006 Feist, *Ann.*, **428**, 25 (1922).
- 1007 Feist, *Ann.*, **428**, 40 (1922).

- 1928 Haerdi and Thorpe, *J. Chem. Soc.*, **127**, 1237 (1925).
- 1929 Ruhemann, *J. Chem. Soc.*, **97**, 457 (1910).
- 1930 Ruhemann, *Ber.*, **53**, 287 (1920).
- 1931 Walker, *J. Am. Chem. Soc.*, **76**, 309 (1954).
- 1932 Ruhemann and Stapleton, *J. Chem. Soc.*, **77**, 239 (1900).
- 1933 Grob and Camenisch, *Helv. Chim. Acta*, **36**, 49 (1953).
- 1934 Lambert and Piggott, *J. Chem. Soc.*, **1947**, 1489.
- 1935 Hale and Robertson, *Am. Chem. J.*, **39**, 685 (1908), cf. Hale, *Ber.*, **45**, 1600 (1912).
- 1936 Fanta and Stein, *J. Am. Chem. Soc.*, **77**, 1045 (1955).
- 1937 Bahner, U.S. pat. 2,425,276 [*C.A.*, **41**, 7410 (1947)].
- 1938 Bahner, U.S. pat. 2,426,158 [*C.A.*, **41**, 7410 (1947)].
- 1939 Bahner, U.S. pat. 2,447,626 [*C.A.*, **42**, 8819 (1948)].
- 1940 Bahner, U.S. pat. 2,431,451 [*C.A.*, **42**, 2615 (1948)].
- 1941 Snyder and Hamlin, *J. Am. Chem. Soc.*, **72**, 5082 (1950).
- 1942 J. F. Boardland, Thesis, Purdue University, 1941, quoted by Hass and Riley in *Chem. Revs.*, **32**, 414 (1943).
- 1943 Shechter and Conrad, *J. Am. Chem. Soc.*, **76**, 2716 (1954).
- 1944 Dornow and Wiehler, *Ann.*, **578**, 113 (1952).
- 1945 Pessakova and Sopova, *Zhur. Obshchei Khim.*, **24**, 513 (1954); *Doklady Akad. Nauk S.S.S.R.*, **95**, 993 (1954) [*C.A.*, **49**, 6180-6181 (1955)].
- 1946 Dornow and Menzel, *Ann.*, **588**, 40 (1954).
- 1947 Heim, *Ber.*, **44**, 2016 (1911).
- 1948 Smith and Kelly, *J. Am. Chem. Soc.*, **74**, 3300 (1952).
- 1949 Smith and Davis, *J. Am. Chem. Soc.*, **76**, 5376 (1954).
- 1950 Buckley, Charlsh, and Rose, *J. Chem. Soc.*, **1947**, 1514.
- 1951 Smith and Davis, *J. Org. Chem.*, **15**, 824 (1950).
- 1952 Kohler and Potter, *J. Am. Chem. Soc.*, **57**, 1316 (1935).
- 1953 Backer, *Rec. trav. chim.*, **72**, 119 (1953).
- 1954 Doering and Weil, *J. Am. Chem. Soc.*, **69**, 2461 (1947).
- 1955 Boekelheide and Rothchild, *J. Am. Chem. Soc.*, **71**, 879 (1949).
- 1956 Winterfeld and Heinen, *Ann.*, **573**, 85 (1951); **578**, 171 (1952).
- 1957 Boekelheide and Rothchild, *J. Am. Chem. Soc.*, **69**, 3149 (1947).
- 1958 Wilt and Levine, *J. Am. Chem. Soc.*, **75**, 1368 (1953).
- 1959 Winterfeld, Wald, and Rink, *Ann.*, **588**, 125 (1954).
- 1960 Winterfeld, Wald, and Rink, *Naturwiss.*, **41**, 230 (1954) [*C.A.*, **49**, 14759 (1955)].
- 1961 Boekelheide and Mason, *J. Am. Chem. Soc.*, **73**, 2356 (1951).
- 1962 Clifford, U.S. pat. 2,579,419 [*C.A.*, **46**, 7593 (1952)].
- 1963 Boekelheide and Marinetti, *J. Am. Chem. Soc.*, **73**, 4015 (1951).
- 1964 Boekelheide and Sieg, *J. Org. Chem.*, **19**, 587 (1954).
- 1965 Furukawa and Gershman, *Zhur. Obshchei Khim.*, **23**, 267 (1953) [*C.A.*, **48**, 2573 (1954)].

AUTHOR INDEX, VOLUMES 1-10

Adams, Joe T., 8
Adkins, Homer, 8
Angyal, S. J., 8

Bachmann, W. E., 1, 2
Behr, Lyell C., 6
Bergmann, Ernst D., 10
Berliner, Ernst, 5
Blatt, A. H., 1
Blicke, F. F., 1
Brewster, James H., 7
Brown, Weldon G., 6
Bruson, Herman Alexander, 5
Buck, Johannes S., 4
Butz, Lewis S., 5

Carmack, Marvin, 3
Carter, H. E., 3
Cason, James, 4
Cope, Arthur C., 9
Corey, Elias J., 9
Crounse, Nathan N., 5

Daub, Guido S., 6
DeTar, DeLos F., 9
Djerassi, Carl, 6
Drake, Nathan L., 1
DuBois, Adrien S., 5

Eliel, Ernst L., 7
Emerson, William S., 4
England, D. C., 6

Fieser, Louis F., 1
Folkers, Karl, 6
Fuson, Reynold C., 1

Geissman, T. A., 2
Gensler, Walter J., 6
Gilman, Henry, 6, 8
Ginsburg, David, 10

Govindichari, Tuticorin R., 6
Gutsche, C. David, 8

Hageman, Howard A., 7
Hamilton, Cliff S., 2
Hamlin, K. E., 9
Hanford, W. E., 3
Hartung, Walter H., 7
Hassall, C. H., 9
Hauser, Charles R., 1, 8
Henne, Albert L., 2
Hoffman, Roger A., 2
Holmes, H. L., 4, 9
House, Herbert O., 9
Hudson, Boyd E., Jr., 1

Ide, Walter S., 4
Ingersoll, A. W., 2

Jackson, Ernest L., 2
Jacobs, Thomas L., 5
Johnson, John R., 1
Johnson, William S., 2, 6
Jones, Reuben G., 6

Kloetzel, Milton C., 4
Kornblum, Nathan, 2
Kosolapoff, Gennady M., 6
Kulka, Marshall, 7

Lane, John F., 3
Leffler, Marlin T., 1

McElvain, S. M., 4
McKeever, C. H., 1
Magerlein, Barney J., 5
Manske, Richard H. F., 7
Martin, Elmore L., 1
Moore, Maurice L., 5
Morgan, Jack F., 2
Morton, John W., Jr., 8
Mosettig, Erich, 4, 8
Mozingo, Ralph, 4

Newman, Melvin S., 5

Pappo, Raphael, 10

Parmerter, Stanley M., 10

Phadke, Ragini, 7

Phillips, Robert R., 10

Price, Charles C., 3

Rabjohn, Norman, 5

Roe, Arthur, 5

Rytina, Anton W., 5

Sauer, John C., 3

Sethna, Suresh, 7

Sheehan, John C., 9

Shirley, David A., 8

Shriner, Ralph L., 1

Simonoff, Robert, 7

Smith, Lee Irvin, 1

Smith, Peter A. S., 3

Spielman, M. A., 3

Spoerri, Paul E., 5

Struve, W. S., 1

Suter, C. M., 3

Swamer, Frederic W., 8

Swern, Daniel, 7

Tarbell, D. Stanley, 2

Todd, David, 4

Touster, Oscar, 7

Truce, William E., 9

Wallis, Everett S., 3

Weston, Arthur W., 3, 9

Whaley, Wilson M., 6

Wilds, A. L., 2

Wiley, Richard H., 6

Wilson, C. V., 9

Wolf, Donald E., 6

Wolff, Hans, 3

Wood, John L., 3

Zaugg, Harold E., 8

CHAPTER INDEX, VOLUMES 1-10

- Acetoacetic ester condensation and related reactions, 1
- Acetylenes, 5
- Acylation of ketones to β -diketones or β -keto aldehydes, 8
- Acyloins, 4
- Aliphatic fluorine compounds, 2
- Alkylation of aromatic compounds by the Friedel-Crafts method, 3
- Alkylation of esters and nitriles, 9
- Amination of heterocyclic bases by alkali amides, 1
- Arndt-Eistert synthesis, 1
- Aromatic arsonic and arsinic acids, 2
- Aromatic fluorine compounds, 5
- Az lactones, 3

- Baeyer-Villiger oxidation of aldehydes and ketones, 9
- Benzoin, 4
- Biaryls, 2
- Bischler-Napieralski synthesis of 3,4-dihydroisoquinolines, 6
- Bucherer reaction, 1

- Cannizzaro reaction, 2
- Carbon-carbon alkylation with amines and ammonium salts, 7
- Catalytic hydrogenation of esters to alcohols, 8
- Chloromethylation of aromatic compounds, 1
- Claissen rearrangement, 2
- Cleavage of non-enolizable ketones with sodium amide, 9
- Clemmensen reduction, 1
- Coupling of diazonium salts with aliphatic carbon atoms, 10
- Curtius reaction, 3
- Cyanoethylation, 5
- Cyclic ketones by intramolecular acylation, 2

- Darzens glycidic ester condensation, 5
- Diels-Alder reaction: ethylenic and acetylenic dienophiles, 4
- Diels-Alder reaction with cyclenones, 5
- Diels-Alder reaction with maleic anhydride, 4
- Direct sulfonation of aromatic hydrocarbons and their halogen derivatives, 3

- Elbs reaction, 1
- Epoxidation of ethylenic compounds with organic peracids, 7

- Friedel-Crafts reaction with aliphatic dibasic acid anhydrides, 5
- Fries reaction, 1

- Gattermann-Koch reaction, 5
- Gattermann synthesis of aldehydes, 9

- Halogen-metal interconversion reaction with organolithium compounds, 6
- Hoesch synthesis, 5
- Hofmann reaction, 3
- Hydrogenolysis of benzyl groups, 7
- Hydroxylation of ethylenic compounds with organic peracids, 7

- Jacobsen reaction, 1
- Japp-Klingemann reaction, 10

- β -Lactams, 9
- β -Lactones, 8
- Leuckart reaction, 5

- Mannich reaction, 1
- Metalation with organolithium compounds, 8
- Michael reaction, 10

- Nitrosation of aliphatic carbon atoms, 7

Oppenauer oxidation, 6

Pechmann reaction, 7

Periodic acid oxidation, 2

Perkin reaction and related reactions, 1

Pictet-Spengler synthesis of tetrahydroisoquinolines, 6

Pomeranz-Fritsch synthesis of isoquinolines, 6

Preparation of amines by reductive alkylation, 4

Preparation of benzoquinones by oxidation, 4

Preparation of ketenes and ketene dimers, 3

Preparation of phosphonic and phosphinic acids, 6

Preparation of thiazoles, 6

Preparation of thiophenes and tetrahydrothiophenes, 6

Pschorr synthesis and related ring closure reactions, 9

Reaction of diazomethane and its derivatives with aldehydes and ketones, 8

Reaction of halogens with silver salts of carboxylic acids, 9

Reduction with aluminum alkoxides, 2
Reduction with lithium aluminum hydride, 6

Reformatsky reaction, 1

Replacement of aromatic primary amino groups by hydrogen, 2

Resolution of alcohols, 2

Rosenmund reduction, 4

Schmidt reaction, 3

Selenium dioxide oxidation, 5

Skraup synthesis of quinolines, 7

Sommelet reaction, 8

Stobbe condensation, 6

Substitution and addition reactions of thiocyanogen, 3

Synthesis of aldehydes from carboxylic acids, 8

Synthesis of ketones from acid chlorides and organometallic compounds of magnesium, zinc, and cadmium, 8

von Braun cyanogen bromide reaction, 7

Willgerodt reaction, 3

Wolff-Kishner reduction, 4

SUBJECT INDEX, VOLUME 10

Since the tables of contents of the individual chapters provide a quite complete index, only those items which are not readily found on the contents pages are indexed here.

Numbers in **boldface** type refer to experimental procedures.

- γ -Acetamido- γ -carbethoxy- γ -cyano-butylaldehyde, **267**
- Acetonylpyridinium bromide, reaction with diazonium salts, 8
- Alkylidenerhodanines, use in Michael reaction, 220
- Amidrazones, 30
- Amino acids, synthesis via Japp-Klingemann reaction, 153, 155-156
- synthesis via Michael reaction, 263
- Aromatic rings, synthesis via Michael reaction, 254-256
- Arylazosulfones, 18
- Azines, use in Michael reaction, 209
- Betaines, synthesis using diazonium salts, 8, 18
- Borsche synthesis of cinnolines, 28
- Cannizzaro reaction, intramolecular, 210
- 1-Carbethoxy-2,3-phthaloylpyrrocoline, 227
- 4-Carbomethoxy-7-nitro-2-phenyl-1(2)-phthalazone, 16
- Cinnolines, 4-hydroxy-, from diazonium salts, 6-7, 9, 27-28
- Widman-Stoermer synthesis, 21, 28
- Cleavage of Michael adducts, 188-191
- Condensed alicyclic compounds, synthesis via Michael reaction, 215-216, 220-221, 249-251
- Coumarins, 225, 227
- Coupling of diazonium salts with aliphatic carbon atoms, 1-142
- elimination of groups during, 10-12, 18, 20, 22-23, 25-27; *see also* Japp-Klingemann reaction
- Cyclobutanes, synthesis via Michael reaction, 237, 248
- Cyclobutanones as intermediates in abnormal Michael reaction, 193-197
- 1,2-Cyclohexanedione monophenylhydrazones, **159**
- Cyclohexanes, synthesis via Michael reaction, 249
- Cyclopentanes, synthesis via Michael reaction, 248
- Cyclopropanes, synthesis via Michael reaction, 248
- 2,4,6,8-Decatetrayne, as acceptor in Michael reaction, 183
- Diazonium salts, coupling with aliphatic carbon atoms, 1-142
- reversal of the coupling, 147
- reaction with hydrazones, 4-6
- reactivity of methylene compounds toward, 31
- Diethyl α , β -diphenylglutarate, **269**
- Diethyl glutaconate, reaction with diazonium salts, 14-15
- self-condensation, 234
- Diethyl 6-keto-4-methyl-2-heptene-1,5-dicarboxylate, **269**
- Diethyl vinylphosphonate, use in Michael reaction, 241
- Dimerization, of 3,5-dimethyl-2-cyclohexen-1-one, 222
- of 2-ethyl-2-hexenal, 210
- of methyl acrylate, 234
- of piperitone, 221
- Dimethylbenzofulvene, behavior in Michael reaction, 232
- Dimethyl (α -phenyl- β -nitroethyl)-malonate, **269**

- N,N'-Diphenyl-C-methylformazan, 24, **34**
N,N'-Diphenyl-C-nitroformazan, 19
Dypnopinacol, 216-217
- Ethyl α -benzoyl- γ -(2-pyridyl)butyrate, **270**
Ethyl cyanoglyoxalate *m*-chlorophenylhydrazine, **33**
Ethyl α,β -dioxobutyrate α -phenylhydrazine, **32**
Ethyl pyruvate *o*-nitrophenylhydrazine, **159**
- Formazans, preparation via diazonium salts, 9, 11, 13-15, 19, 24, 158
Formazyl chloride, 14
- Hagemann ester, 251
Hansa yellows, 13
Heterocyclic rings, synthesis via Michael reaction, 256-263; *see also* individual heterocyclic rings, e.g. Pyridines
Hexaethyl 3-butene-1,1,2,2,3,4-hexacarboxylate, **269**
Holden-Lapworth mechanism of abnormal Michael reactions, 193-197
Hydrazones, reaction with diazonium salts, 4-6
 α -Hydrazones of α,β -diketo esters, 11
4-Hydroxy-3-methylcinnoline, **34**
- Indazoles, synthesis via diazonium salts, 15, 17, 24, 29
Indene, behavior in Michael reaction, 232
Indoles, synthesis via Japp-Klingemann reaction, 153
 synthesis via Michael reaction, 226
Isophorone, behavior in Michael reaction, 230
- Japp-Klingemann reaction, 143-178
- 7-Keto-1-methoxy-13-methyl-5,6,7,9,10,13-hexahydrophenanthrene, **267**
trans-3-Keto-2-phenylcyclohexanecarboxylic acid, **268**
- Kojic acid, behavior in Michael reaction, 232
- Mannich bases, use in Michael reaction, 222-223
Mesityl oxide, behavior in Michael reaction, 230
Methyl 3-keto-2-phenylcyclohexyl- α -nitroacetate, **268**
Michael reaction, 179-555
 involving 1,6-addition, 213, 237-238
 involving 1,8-addition, 237
- 1-Nitro-1-*p*-chlorophenylhydrazonoethane, **33**
5-Nitro-4,4-dimethylpentan-2-one, **267**
Nitromalondialdehyde, use in Michael reaction, 240
1-(*p*-Nitrophenylazo)-2,3-dimethyl-1,3-butadiene, **33**
- Phenanthrenes, Pschorr synthesis of, 21-22, 27
Piperidines, synthesis via Michael reaction, 233, 258-261
Pyrans, synthesis via Michael reaction, 257
Pyrazoles, synthesis via Japp-Klingemann reaction, 154
Pyridines, synthesis via Michael reaction, 207-208, 210-212, 214, cf. 236, 258-261
 α -Pyrones, synthesis via Michael reaction, 214-215, 256-257
Pyrroles, synthesis via Michael reaction, 261
Pyrrolizidines, synthesis via Michael reaction, 262
Pyruvaldehyde 1-phenylhydrazone, **32**
- Rearrangement, of carbanions of Michael adducts, 186
 of nitro groups on treatment with diazonium salts, 20, 151
Rhodanine, use in Michael reaction, 220
- Schiff bases, use in Michael reaction, 207-209
Serotonin, 156

Sulfazone, reaction with diazonium salts, 18-19	Triethyl α -acetylcarballylate, 268
Tetrazolium salts, synthesis via dia- zonium salts, 29	Trimethyl propylene-2,3,3-tricarb- oxylate, self-condensation, 234
Thioarbazones, synthesis via diazonium salts, 29-30	Tryptamine, 155
	Widman-Stoermer cinnoline synthesis, 21, 28



2 R02 A0106 18.50

13640

213"nl,N

et al.

